ИЗВЕСТИЯ
АКАДЕМИИ НАУК СССР
СЕРИЯ ГЕОЛОГИЧЕСКАЯ

IZVESTIYA AKAD. NAUK SSSR

SERIYA GEOLOGICHESKAYA

1960 | No. 2, February

CONTENTS

Page

GEOLOGIC FEATURES OF THE FORMATION OF PYRITE DEPOSITS IN THE WESTERN PART OF NORTHERN CAUCASUS, by V.I. Smirnov and T.Ya. Goncharova 1

ASSIMILATION PHENOMENA AS ILLUSTRATED BY MINOR INTRUSIONS OF THE GYUMUSHKHANA COMPLEX, ARMENIA, by A.P. Lebedev and E.G. Malkhasyan 11

ABSOLUTE AGE OF EXTRUSIVE ROCKS IN THE MAGADAN BATHOLITH, by L.V. Firsov 22

CLIMATIC DATA DETERMINING THE LOWER STRATIGRAPHIC BOUNDARY OF THE PLIOCENE, by A.I. Moskvitin 32

ANCIENT SHORELINES OF THE BLACK SEA ALONG THE CAUCASIAN COAST, by P.V. Fedorov 47

PALEOGEOGRAPHIC POSITION OF THE KIZEL CARBONIFEROUS BASIN AND ITS GENETIC FEATURES IN THE LIGHT OF NEW DATA, by N.I. Markovskiy 55

EVOLUTION OF QUATERNARY VOLCANISM IN THE SREDINNYY (MIDDLE) RANGE OF KAMCHATKA, by E.N. Erlikh 65

PETROGRAPHIC SKETCH AND GEOCHEMISTRY OF THE SANDYK MOUNTAINS ALKALIC INTRUSION (NORTHERN KIRGHIZIA), by B.I. Zlobin 77

BORIS VASIL'YEVICH IVANOV (OBITUARY), by G.A. Afanas'yev, V.V. Lapin and A.I. Tsvetkov 88

REVIEWS AND DISCUSSIONS

ON MOVEMENTS OF THE EARTH'S CRUST IN THE SAKHALIN REGION, BETWEEN THE LATE CRETACEOUS AND THE PALEOGENE, by A.A. Kapitsa 90

ON V.D. KOGAN'S PAPER "ORIGIN OF NATIVE SULFUR", by P.M. Murzayev 91

LETTER TO THE EDITORIAL BOARD ON THE CRITICISM OF THE STATUS OF GEOLOGIC SCIENCE, by V.I. Smirnov 92

A REVIEW OF "THEORY OF SEDIMENTARY ROCKS", by A.D. Sultanov, A.N. Solovkin, A.G. Seidov, and D.M. Suleymanov 93

BIBLIOGRAPHY 96

CHRONICLE

FOURTH SESSION OF THE INTERNATIONAL ASSOCIATION FOR GEOLOGIC STUDY OF DEEP ZONES OF THE EARTH'S CRUST, by Ye.V. Pavlovskiy and N.A. Shtreys 116

TWENTY-FIFTH YEAR OF PUBLICATION

T-00404. Approved for printing January 28, 1960.
Circulation - 3,300 copies. Order 3784.
Paper size 70 x 108-1/16. Paper 4. Printing sheets 10.96 Publ. sheets 12.7

Second printing office of the USSR Academy of Sciences Publishing House.
Moscow, Shubinskiy per. 10.

GEOLOGIC FEATURES OF THE FORMATION OF PYRITE DEPOSITS IN THE WESTERN PART OF NORTHERN CAUCASUS[1]

by

V. I. Smirnov and T. Ya. Goncharova

GEOLOGIC STRUCTURE OF THE ORE ZONE

Urup and Beskes are among the important pyrite deposits discovered in the last decade in the western part of northern Caucasus. These deposits are located in the Peredovoy (Front) Range, in the headwaters of Bol'shaya Laba and Urupa rivers, which are the left tributaries of the Kuban, and are associated with a Paleozoic greenstone belt. They are 25.5 kilometers apart.

Volcanic deposits, regionally metamorphosed to greenstone rocks, have been traced for 200 kilometers along the Peredovoy Range. Their widest belts have been observed in the upper Bol'shaya and Malaya Labas, where their thickness reaches 2.5 kilometers; farther east and northeast, they split into two thinner zones.

Because of the strong metamorphism and the lack of a fossil fauna, the time of formation of this greenstone sequence is not definitely clear. Greenstone deposits in the Bol'shaya and Malaya Labas basin are assigned to the lower Paleozoic, because of the presumably Middle Cambrian Archaeocyathid fauna found by V. N. Robinson in the 1920's in the Dzhentu Range limestone overlying green metamorphic schist.

East of there, an Upper Devonian fauna was found later on in sedimentary-volcanic deposits along the Teberda and Aksauta rivers. Because of a gradual transition from the fossiliferous rocks to the underlying greenstones, the volcanics were designated as Middle Devonian. Their composition is close to that of the Laba sequence.

At the present time, volcanic deposits of the Teberda area and to the west are supposed to be Lower to Middle Devonian; greenstones of the Bol'shaya and Malaya Labas basin and to the west are assigned to the Lower Cambrian. The age of metamorphic volcanics in the area between the Bol'shaya Laba and Teberda, particularly the ore-bearing Urup sequence, is interpreted differently by different students. V.I. Dzhumaylo and Ye.A. Snezhko, who carried on geologic surveying in the Urup area, assign the ore-bearing sequence to the Lower and Middle Devonian. V.I. Robinson, who studied the volcanic section along the two Labas, correlates it with the Urup section and believes that the Urup and Beskes greenstone sequences are of the same age, i.e., lower Paleozoic.

The greenstone sequence is represented by sedimentary-volcanic formations of a geosynclinal type. It is divided into two complexes. The lower complex is represented by strongly metamorphosed diabase and porphyrite, interbedded with phyllite. The presence of a great number of interbedded intrusions of an intermediate composition (plagioclase porphyrites) is typical of it. The upper complex is marked by a considerable development of pyroclastic material and by a regular change in composition, from the most basic extrusives at the base to acid near the top (with intermediate varieties in between). A correlation of the Urup and Beskes sedimentary-volcanic sections is given in Figure 1.

This correlation shows that on the whole the ore-carrying greenstone sequence persists over a considerable distance.

In detail, however, the Beskes section is more complex; unlike the Urup section, it has two cycles of volcanic activity, beginning with lavas and culminating in pyroclastic formations. The Beskes ore deposit is stratigraphically somewhat lower than the Urup.

GEOLOGY OF PYRITE DEPOSITS

The Urup deposits are located in the northwest of the Peredovoy Range, in the headwaters of Urup River, a left tributary of the Kuban. The main body of the Urup deposit lies at the base of tuffs of an intermediate composition, which rest on quartz albitophyre. Small subordinate ore bodies are known from the underlying

[1] Geologicheskiye osobennosti obrazovaniya kolchedannykh mestorozhdeniy zapadnoy chasti Severnogo Kavkaza.

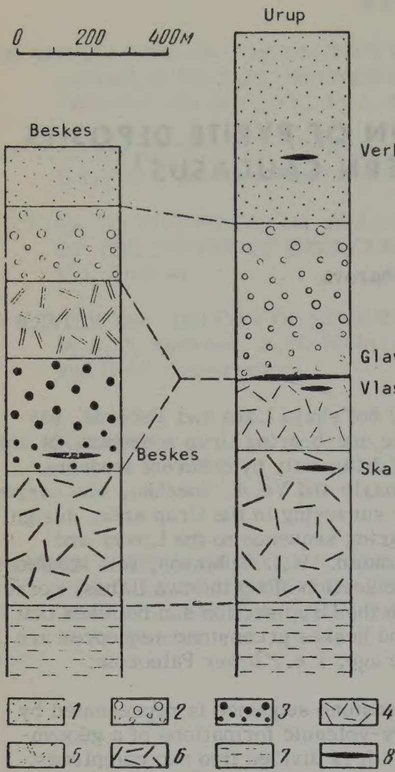

Figure 1. Columnar sections of volcanic rocks in the Beskes and Urup deposits.

1 -- acid tuff; 2 -- tuff of an intermediate composition; 3 -- basic tuff and tuffaceous lava; 4 -- quartz albitophyre; 5 -- plagioclase porphyrite; 6 -- diabase and diabase porphyrite; 7 -- phyllite; 8 -- copper pyrite deposits.

rocks in quartz albitophyre (the Vlasnichikha and Skalistoye deposits), as well as in the overlying acid tuff (the Verkhneye deposit).

Quartz albitophyre which makes up the floor of the main ore body is marked by inconsistent thickness, changing both along the strike and along the dip. In the central sector, the quartz albitophyre is up to 100 to 130 meters thick; it thins to 40 meters to the east and west.

The enclosing rocks are tuff of an intermediate composition, characterized by their variable structure and size of fragments. Coarse clastic varieties, usually thin, gradually change to finely clastic ones which in turn change to very finely clastic tuff and tuffite with layers of sedimentary rocks — siliceous and phyllitic schist. The thickness of intermediate tuff is not constant, changing from west to east: in the central part of the deposit, it is 360 to 380 meters thick, increasing to 450 to 500 m on the eastern flank. Developed immediately above the main ore body, in its hanging wall, is finely clastic tuff of an intermediate composition, alternating with tuffite and siliceous schist. The hanging wall in the central part of the ore body is made up of sealing-wax red jasper-like siliceous meta-shale, from a few tens of centimeters to 25 meters thick. On the flanks, the siliceous shale is a typical sedimentary rock with radiolarian remains; it is a good marker horizon, usually without any mineralization. Only in rare instances does it contain sulfide incrustations, chiefly chalcopyrite. Its contact with the ore body is sharp, either direct or across a thin zone of rapidly alternating red hematitic rocks and green quartz-chlorite schist, carrying sulfides in sparse incrustations and small accumulations.

The ore-bearing volcanics are folded into large gentle flexures, trending latitudinally. Traced in the ore site itself is an asymmetric anticlinal fold with a steeper south limb (dips of 40 to 50°) and a gentle north limb (dips of 10 to 35°). Its axis plunges to the east.

The south limb of this anticline is complicated by trough-like sedimentary downwarps separated by transverse uplifts. The main ore body is related to the northern downwarp; mineralization is absent in uplifts (Fig. 2).

The folded structures are complicated by a pre-Jurassic and post-Lower Jurassic faults. The largest of them are those limiting the ore-bearing sequence on the north and the south. The Urup area moved down along these faults to produce a graben with a fairly complicated structure.

The main ore body is represented by an extended tabular deposit of massive pyrite ores. This body, in sharp contact with the enclosing rocks, rests conformably on them, being folded in the same way. The subordinate ore bodies occur in conformable lentils.

The mineral composition of the ores is fairly simple, the principal ore minerals are pyrite, chalcopyrite, hypogene bornite, and sphalerite; associated and rare minerals are galena, magnetite, hematite, tennantite; quartz, calcite, chlorite, and sericite are the non-ore minerals. Massive and banded ores are most typical, with occasional breccia textures brought about by post-ore deformation, and incrustation ores in the floor rocks. The rock structure is granuloblastic to cataclastic, less commonly blastoporphyritic, with very rare relicts of metacolloid ores. Banded ores are very common, with the banding determined by an alternation of chalcopyritic and pyritic sphalerite layers. A well-defined banding is typical of the bornite and sphalerite ores. The trend of banding always coincides with the bedding and schistosity of the enclosing rocks.

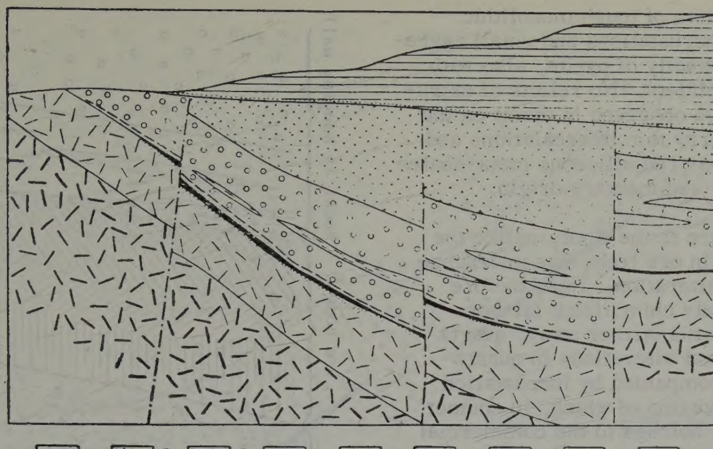

FIGURE 2. Generalized cross-section of the Urup deposit (main body).

1 -- Lower Jurassic sandstone and shale; 2 -- acid tuff; 3 -- tuff of an intermediate composition; 4 -- phyllite intercalations in tuff; 5 -- a layer of jasper-like siliceous meta-shale in the hanging wall of the ore body; 6 -- quartz albitophyre; 7 -- diabase and diabase porphyrite; 8 -- a massive pyrite ore bed; 9 -- incrustation ore in the floor of the ore body.

In composition, the ores may be differentiated into chalcopyrite, copper-zinc, and iron pyrite ores, regularly distributed in the ore body. The hanging wall usually is made up of chalcopyrite ores; the central part, of a copper-zinc mineralization; and the floor, almost always of iron pyrite ores (Fig. 3). The distribution of these ore types is fairly consistent both along the strike and along the dip.

Located in the central part of the main ore body, between siliceous meta-shales of the hanging wall and the massive chalcopyrite ores is a quarttzitic bed. It has been traced over a considerable distance, changing in thickness from 0.2 to 3 m. Its contacts are rectilinear

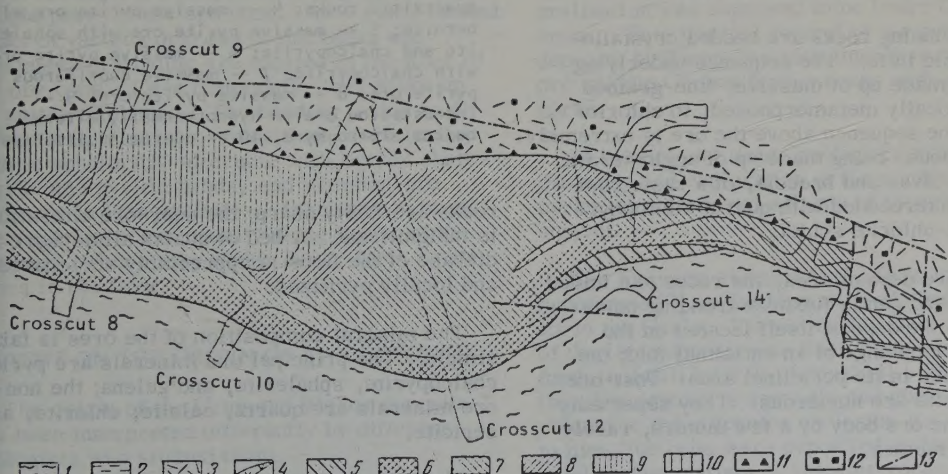

FIGURE 3. Structure of the Urup ore body on the level of drift No. 8, from data of the Urup Geological Exploration Party.

1 -- Siliceous meta-shale; 2 -- quartzite-like rocks; 3 -- quartz albitophyre; 4 -- lamprophyre dikes; 5 -- oxidized ore; 6 -- massive pyrite ore with bornite; 7 -- massive pyrite ore with chalcopyrite and sphalerite; 8 -- massive pyrite ore with chalcopyrite; 9 -- essentially pyrite massive ore with a commercial content of copper; 10 -- essentially pyritic massive ore; 11 -- commercial incrustation of sulfides; 12 -- non-commerical sulfide incrustation; 13 -- faults.

and sharp. It consists of tough monolithic rocks, often with incrustations and small aggregates of sulfides, usually of pyrite, also with fine chalcopyrite veinlets. No relicts of extrusive rocks have been observed in them; on the other hand, they carry thin intercalations and lenses of sealing-wax red siliceous meta-shales corroborating their sedimentary origin.

Quartz albitophyre in the floor, unlike the rocks above the main ore body, has undergone a distinct thermal alteration. Near the ore body, it is intensively chloritized; farther away, sericitized; still farther away, quartzitized. Hydrothermal alterations in quartz albitophyre are accompanied by incrustation mineralization, a portion of which, in contact with massive ores, belongs to the commercial copper ores. The outline of the hydrothermally altered zone is sinuous, with offshoots away from the ore body, along weakened and more permeable zones, over a distance of a few tens of meters (Fig. 4).

Intrusive rocks in the Urup ore deposit are few, being represented by isolated dikes of felsite, granodiorite, and kersantite, occurring among phyllites; also by rare dikes of lamprophyres among ore bodies and among rocks immediately contacting them. The lamprophyre dikes are fairly intensively altered, slightly faulted together with the enclosing ore bodies, and cut by chalcopyrite veins along fractures in near-wall segments and along the faults.

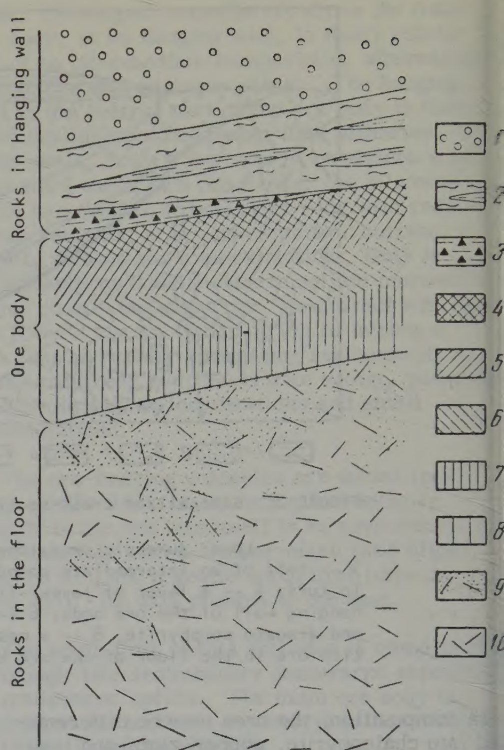

FIGURE 4. Geologic section of the ore body and enclosing rocks of the Main Urup Deposit

1 -- tuff of an intermediate composition; 2 -- sealing-wax red siliceous meta-shale interbedded with green siliceous schist; 3 -- quartzitic rocks; 4 -- massive pyrite ore with bornite; 5 -- massive pyrite ore with sphalerite and chalcopyrite; 6 -- massive pyrite ore with chalcopyrite; 7 -- massive cupriferous pyrite ore; 8 -- massive pyrite ore; 9 -- incrustation ore in hydrothermally altered quartz albitophyre; 10 -- quartz albitophyre.

The Beskes ore deposit is located in the northwest of the Peredovoy Range, in the Bol'shaya and Malaya Labas watershed.

The enclosing rocks are bedded crystalloclastic basic tuffs. The sequence underlying the ore is made up of massive, fine-grained diabase, locally metamorphosed, to chlorite schist. The sequence above the ore is extremely heterogeneous, being made up of agglomeratic tuffaceous lavas and breccia, of a basic composition, interbedded with quartz albitophyre and quartz-chlorite schist.

In the ore deposit area, the rocks are folded into large and gentle flexures trending northwest, with the deposit itself located on the northwestern plunge of an anticlinal fold; the ore body lies in its periclinal area. Post-ore normal faults are numerous. They repeatedly displace the ore body by a few meters, rarely by tens of meters.

The tabular ore body is conformable with the emplacing rocks and is involved in all details of their structure (Fig. 5). With a generally monoclinal position of the ore body, with a northeastern strike and northwesterly dips at 30 to 40°, it exhibits very gentle folds with axes parallel to the dip of the deposit. Contacts of the ore body with the enclosing rocks are fairly sharp; the near-ore alteration is insignificant. A bed of quartz albitophyre in diabase of the floor is appreciably sericitized and locally pyritized.

The mineral composition of the ores is fairly simple. The principal ore minerals are pyrite, chalcopyrite, sphalerite, and galena; the non-ore minerals are quartz, calcite, chlorite, and sericite.

Most common are massive and banded ores, with incrustation mineralization less common. In fault zones, the ores are brecciated. Their structures are fairly diversified, the most common being redeposition structures with cataclastic phenomena and recrystallization, which occurred during the process of metamorphism.

Massive ores are the most common; they

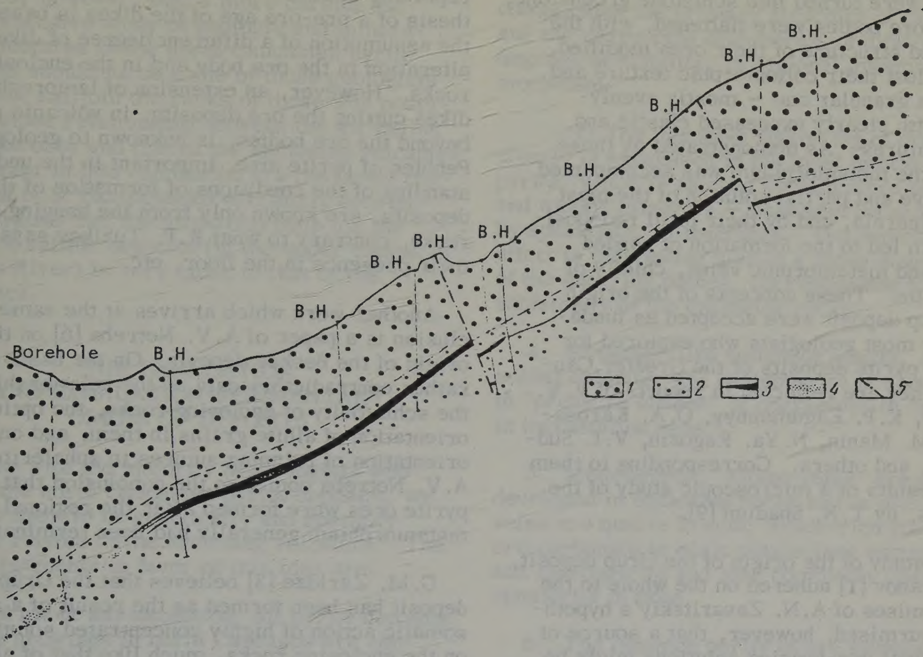

FIGURE 5. Cross-section of the Beskes deposit, after N.T. Butov.

1 -- agglomeratic tuffaceous lava and diabase breccias interbedded with amygdaloidal diabase and quartz-chlorite schist; 2 -- bedded crystalloclastic tuff of diabase, interbedded with massive fine-grained diabase; 3 -- massive copper pyrite ore; 4 -- pyrite incrustations; 5 -- faults.

ake up bulges as well as the hanging wall and iddle parts of the ore body. As a rule, banded ocks of various degrees of thickness and arpness in banding are located in the floor of e ore body. Less commonly, they make up s entire thickness. The banding is due to differences in mineral composition: dark bands, ich in sphalerite, alternate with lighter chalcoyritic and pyritic bands, and with non-ore inerals in lean varieties. Incrustation ores re rare and occur usually along flanks of the re body, where they wedge out or form small ones in the floor.

VIEWS ON THE ORIGIN OF THE DEPOSITS

The origin of the Urup and Beskes deposits as been interpreted differently by different eologists who studied them.

At the initial period of exploration of the eskes deposit, in 1950-1954, V.A. Mel'nikov nd B.P. Nikitin regarded it as high-temperature ydrothermal, and genetically related to Hernian granitoids known in the area, in small odies. The presence of a large plutonic body as assumed in the middle of a dome-like fold ith which the deposit was associated. The ancestral intrusion, and consequently the mineralization was supposed to be lower Carboniferous. This implied control of the pyrite deposits by dome-like anticlinal structures in pre-middle Carboniferous rocks with granitoid cores.

At the present time, geologists working on the study and exploration of the north Caucasian pyrite ores form two schools of thought on that subject.

The majority accepts A.N. Zavaritskiy's hypothesis [2] on the formation of similar deposits in the Urals. Viewed in this light, the origin of the Urup deposit was first studied and set forth in detail by N.V. Ivanov [4]. He believes that this deposit is spatially and genetically related to the volcanics enclosing it. According to him, the ores were deposited as the result of a gel metasomatism of volcanic rocks, after their formation. The zones most susceptible to such a process were replaced in that way; in his opinion, they were the bedding planes of volcanic and sedimentary rocks and the contacts of volconic rocks of different acidity. Such was the origin of the conformable ore. Subsequently, the extrusive and extrusive-sedimentary rocks together with the ores they carried underwent

regional metamorphism. In that process, the volcanics were turned into schistose greenstone, while the ore bodies were flattened, with the texture and structure of their ores modified. The ores lost their collomorphic texture and acquired a granular one — mostly evenly-grained with clearly expressed clastic and blastic features. As demonstrated by those authors, the metamorphism was accompanied by selective and partial solution of the most mobile minerals, and by their local redeposition, which led to the formation of banded textures and metamorphic veins, chiefly of chalcopyrite. These concepts of the origin of the Urup deposit were accepted as fundamental by most geologists who explored for Paleozoic pyrite deposits of the Greater Caucasus. They are reflected in reports of V. V. Gritsenko, K. P. Zagumennyy, O. A. Karosanidze, I. M. Manin, N. Ya. Ragozin, V. I. Sudzilovskiy, and others. Corresponding to them are the results of a microscopic study of the Urup ores, by T. N. Shadlun [9].

In his study of the origin of the Urup deposit, I. Ya. Baranov [1] adhered on the whole to the basic premises of A. N. Zavaritskiy's hypothesis; he surmised, however, that a source of hydrothermal ore-bearing solutions might be, besides volcanic centers and hearths, hypabyssal intrusions of syenite-granodiorite rocks, such as those discovered in the vicinity of this deposit.

N. T. Butov, who directed the recent exploration of the Beskes deposit, associates the formation of pyrite deposits with that of subvolcanic quartz albitophyre, contemporaneous with acid extrusives which terminate the volcanic sequence. In so doing, he times the mineralization with the concluding stage of volcanism and estimates the depth of formation of ore bodies at 700 to 800 meters.

Some geologists believe that Paleozoic pyrite deposits of the northern Caucasus have no direct connection with the enclosing volcanics; they assign these deposits to post-metamorphic hydrothermal metasomatic formations. Published works of the advocates of such views are replete with various specific geologic and mineralogic examples interpreted to substantiate a post-metamorphic origin of pyrite deposits. As an example, there is the paper of R. P. Tuzikov [8] on the origin of the Urup deposit. It cites some data on the relationship of dikes and ore bodies, on the schistosity of ore bodies and the enclosing rocks, on metamorphic veinlets, on certain textural and structural features of ores, and on ore fragments in the enclosing rocks. On the basis of these specific examples, the author comes to the conclusion that the ore bodies of this deposit were formed in schistose rocks, after their metamorphism. We are amazed not only by the one-sided interpretation of some geologic and mineralogic details in R. P. Tuzikov's paper, but by his inaccurate reporting of facts. For instance, that author's thesis of a pre-ore age of the dikes is based on the assumption of a different degree of dike alteration in the ore body and in the enclosing rocks. However, an extension of lamprophyre dikes cutting the ore deposits, in volcanic rocks beyond the ore bodies, is unknown to geologists Pebbles of pyrite size, important in the understanding of the conditions of formation of these deposits, are known only from the hanging wall rocks, contrary to what R. P. Tuzikov says of their presence in the floor, etc.

Another work which arrives at the same conclusion is a paper of A. V. Netreba [6] on the origin of the Beskes deposit. On the basis of rather contradictory data on the relationship of the schistosity of enclosing rocks, the optical orientation of albite grains in them, and on the orientation of twinning sutures in sphalerite, A. V. Netreba comes to the conclusion that the pyrite ores were formed after the regional metamorphism generally had been terminated.

G. M. Zaridze [3] believes that the Urup deposit has been formed as the result of a metasomatic action of highly concentrated solutions on the enclosing rocks, much like that of alkalic rich granitizing solutions. The author believes this process to be generally much later than the formation of the enclosing sequence. He times it with the tectonic phase which has deformed the Paleozoic sedimentary-volcanic formation. The absence of granite massifs in this formation suggests to the author that in places perhaps, very active solutions rich in ore elements rise up from the depths of geosynclinal formations, instead of alkali-rich granitizing solutions; such solutions form metasomatic ore bodies.

No less curious views on the origin of the Beskes deposit were voiced comparatively recently by N. S. Skripchenko. He believed that deposit to be hydrothermal metasomatic, formed considerably later than the regional metamorphism of the volcanics. He arrived at that conclusion by assuming (parenthetically, without any justification) that sulfide mineralization came about after the formation of faults which cut the metamorphic rocks. According to him, the pyrite bodies were formed in metasomatic replacement of hematitic quartzite beds whose intercalations are known to be present in pyrite deposits. These hematitic quartzite beds are primary sedimentary formations, having originated as siliceous ferruginous colloids deposited during submarine volcanic activity and then recrystallized. In the N. S. Skripchenko concept they became pyrite deposits as a result of the action of post-metamorphic hydrothermal solutions saturated with hydrogen sulfide.

A critical consideration of the arguments and concepts of the above-named geologists is beyond the scope of this paper. Only a few of their

emises will be touched upon below. It should e noted, however, that a more careful and mprehensive study of geologic and minera-gic features of the north Caucasian pyrite posits should force some of those geologists recant and join the ranks of those who postu-te a close relationship between the formation pyrite ores and that of the enclosing volcanics. gnificant in this connection are the latest con-pts of N. S. Skripchenko who fairly convinc-gly argues that the formation time for the izylkol sulfide deposits (in the upper course of udes River) is very close to that of the lcanics.

THE EXHALATION AND EXHALATION-SEDIMENTARY ORIGIN OF DEPOSITS

Along with the majority of geologists who uied the north Caucasian pyrite deposits, we lieve them to be genetically and spatially osely related to the enclosing volcanics. The ain arguments in favor of this idea are:

1. Without any exception, all pyrite deposits id ore showings in north Caucasus are con-ned to volcanic rocks having undergone some gree of greenstone metamorphism. The ree belts of volcanic rocks in the Peredovoy ange, 1 to 10 kilometers wide and 200 km long, e known to carry three sizable copper-zinc rite deposits and about ten ore showings. rite deposits are unknown outside these vol-nic rock belts.

2. Within these belts, the maximum concen-ation of pyrite mineralization is toward the nters of volcanic activity, probably connected ith hearths of a central type. The most com-ete volcanic sections are observed here and e maximum thicknesses of extrusive rocks, hich gradually decreases laterally, at times ainst the increase in thickness of pyroclastic ffaceous sediments. According to Ye. A. iezhko, one such volcanic center is located in e Urup deposit; another one, according to . S. Kizeval'ter, lies in the Kizyl'kol deposit.

3. The degree of metamorphism of the rite ore corresponds to that of the enclosing cks. Metamorphism of the Urup and Khudes res, after it had been described by N. V. Ivanov] and T. N. Shadlun [9], was confirmed by any geologists and is no longer doubted by un-iased students. The following evidence sup-orts the fact of metamorphism:

a) Rocks in the ore areas are schistose. he schistosity is most intensive in finely clas-c varieties and in near-contact zones of rocks f different competence, especially near the alls of massive pyrite ore; common in such ones are tectonic breccias, plication, and dense etworks of ore-free quartz-carbonate veins.

b) The wide development of banded ores complicates the primary structure of the ore, and the regrouping of minerals of different degrees of mobility, in regional dynamometa-morphism.

c) The intensive shattering of ores, clearly is expressed in the most brittle mineral, pyrite, which is patched up with more plastic and mobile minerals — chalcopyrite and partly by sphalerite, in fractures. The cataclastic effect is manifested also in a close disposition of the shearing planes, corresponding to schistosity of the enclosing rocks.

4. Streamer-like columnar quartz, coarse-scaled chlorite, and chalcopyrite is accumulated in "pressure shades" of coarse pyrite crystals in incrustation ores.

5. Metamorphic "Alpine veins" are widely developed in enclosing rocks and in ores; these veins are quartz in acid, silica-rich rock; they are carbonate in basic plagioclase extrusives; and chalcopyrite and less commonly chalcopyrite-sphalerite in ores.

6. The common purity of ore minerals, the scarcity of microscopic inclusions of other min-erals in them, the presence of chalcopyrite and sphalerite twinning, and the superposition of cubes on the dodecahedral grains of pyrite are evidences of recrystallization of ore minerals in the process of metamorphism [8].

The older Urup and Beskes deposits, associ-ated with lower to middle Paleozoic fairly inten-sive extrusive and sedimentary rocks, exhibit a degree of metamorphism greater than that of younger deposits in the upper Khudes course, where they are associated with less meta-morphosed upper Paleozoic volcanics. Ores in these younger deposits abound in collomorphic textures; they carry melnikovite, marcasite, opal, zeolites, and gypsum, absent in older deposits; and are marked by weak cataclastic phenomena.

The strongest argument against assigning the north Caucasian pyrite deposits to formations syngenetic with the enclosing rocks, is the rela-tionship between dikes in the extrusive rocks and those in the ore bodies. Most of the ore beds are known to carry dikes, including lampro-phyres (Urup, Kizylkol) and diabase and diorite porphyry (Kizylkol). These dikes cut the ore deposits; at the same time, they are metamor-phosed in their own right, in places faulted together with the ore bodies, and carry fine veins of sulfides. These alterations, along with the presence of veins, led to the belief that the dikes had been formed prior to the ore bodies. This interpretation of the age relationship be-tween dikes and mineralization has been and still is the main argument of those who advocate a post-metamorphic origin for the pyrite deposits.

However, a detailed study of dikes and the ore bodies, particularly in the Urup deposit, shows that the alteration of local lamprophyre dikes does not have the specific features of hydrothermal metamorphism and is not different from metamorphism of the enclosing rocks. Furthermore, ore veins, represented chiefly by hair-like cracks in near-wall segments of dikes, are filled exclusively by chalcopyrite, i. e., by a mineral readily penetrating an ore-bearing rock, in the process of metamorphism. Finally, the extent of dikes is controlled by fractures breaking up the ore bodies. All this suggests the intrusion of dikes into ore bodies and their subsequent common metamorphism; it cannot be taken as evidence of a post-metamorphic origin for the pyrite deposits.

A study of the geologic features of north Caucasian pyrite deposits shows that some of them exhibit evidence of being marine exhalation-sedimentary formations. Such evidence is most clear in the main body of the Urup pyrite ores. It is characterized by the following features:

1. Regular stratification, only slightly complicated by an alternation of locally thicker and thinner segments.

2. A definite stratigraphic position of the ore stratum, conformable with volcanic rocks enclosing it, in the middle part of the section.

3. The position of the ore deposits at the base of marine volcanics represented by finely-clastic tuffs which overlie the extrusive part of the section. Both the extrusives and the tuffs are submarine formations, as witness the presence in them of phyllite and siliceous meta-shale intercalations. Among the overlying coarsely clastic tuff, more porous and brittle, i. e., most favorable for metasomatic replacement, the mineralization is lacking.

4. A close association of the pyrite deposit with a bed of sealing-wax red siliceous meta-shale whose original sedimentary nature is confirmed by the presence of radiolarian remains. The main Urup deposit is terminated by these shales. Similar sealing-wax red meta-shales are known also from enclosing rocks of the Beskes, Kizylkol, and other pyrite deposits of north Caucasus.

5. The association of the ore body — as demonstrated by Ye. A. Snezhko, G. I. Baranov, and N. A. Dobrorodnyy — with a trough-like depression in the vicinity of the Kutsaya Mountain volcanic uplift. According to Ye. A. Snezhko, a central type volcanic vent may be present in the latter area.

6. The absence of any substantial and clean-cut pre-ore structural displacements. The ore stratum was folded together with the enclosing rocks; and together with them, it was broken by post-ore normal faults. Disjointed segments of the same folds are traceable in adjacent fault blocks. This indicates that the folding which involved the ore body was older than the faulting.

7. The simple, evenly distributed, fine-grained massive pyrite, formed as the result of a single-stage process. The gradual zoned change of copper ores to copper-zinc and pyrite, going from the hanging wall to the floor, is not controlled by any intra-ore structures and is demonstrated in the distribution of the strata. The local and very small accumulation of sphalerite and especially of chalcopyrite along fractures in the massive ore and enclosing rocks is readily explained by redeposition of these minerals in the process of metamorphism.

8. The absence of evidence of metasomatic ore formation. There are no unreplaced remnants of enclosing rocks in stratified massive pyrite ores of the main body, in sharp contact with the enclosing rocks. On the contrary, locally present in the ore body, especially on the hanging-wall side, there are short and thin intercalations of green and sealing-wax red siliceous meta-shales.

9. A very important fact, proving the syngenetic origin of the main Urup ore body and the enclosing rocks, is the fairly common occurrence of massive pyrite ores in tuff above the ore. That was noted in early years of exploration in the Urup. Fragments of such ores have been constantly recorded in the description of cores from boreholes which are the main means of exploration of the deposit. They occur 65 to 90 meters above the ore body, and higher up, mostly in coarse clastic tuff. The fragments are irregular in form, at times angular, more commonly oval, like marine pebbles, ranging in size from a crumb 4 to 6 centimeters along the major axis. Their mineral composition is identical to that of the Urup ores. The sulfide grains within them show no signs of concentric zonation or radial arrangement. On the contrary, coarse sulfide grains are cut off by the fragments' boundaries. The absence of growth zones in the pyrite grains, their utter purity, the development of a dense network of fine cleavage fractures close to each other, the presence of simple twins in chalcopyrite and of its hieroglyphic intergrowths with bornite, as well as the development of fine microscopic apophyses of chalcopyrite in schistosity planes of the enclosing rocks — all point to metamorphism in common with the enclosing rocks. The presence of chunks of ore from the hanging wall in the clastic tuffaceous material (above) can be explained only by disintegration of a part of the ore body during the accumulation of the overlying rocks.

10. A distinctive feature of the main Urup ore body is the asymmetric character of the

ntact alteration in the enclosing rocks. It s noted during early exploration of the deposit d it figures as a specific feature of the latter reports of O. A. Karosanidze and other geolo- sts. Quartz albitophyre underlying the ore dy is chloritized, sericitized, quartzitic, d sulfidic, locally over a distance of tens meters. On the other hand, there is no preciable alteration of the overlying rock presented by siliceous schist and fine-grained ff of an intermediate composition. Such a e-sided alteration, on the hanging wall side one, can be explained only by a seepage of hot ineralized solutions through these rocks, th a subsequent passage of those solutions to e sea bottom.

CONCLUSION

In our opinion, the Urup and Beskes pyrite posits, like similar deposits in the northern ucasus, are syngenetic with the enclosing dimentary volcanic rocks and are closely lated to the latter. These deposits were rmed in geosynclines, in a pre-folding period the latter's development, in the presence of bstantial downwarping accompanied by a sub- arine flow of basic and intermediate lavas.

In periods of volcanic quiescence, hot gas- ater vapor emanations seeped through the lava eets, reworked them, and enriched the basin aters in silica, iron, and other elements. nese elements, finding themselves in the bot- m part of a marine basin, very different in s physical chemical aspect, were precipitated various compounds and accumulated at the ottom, mostly in natural basins. Depending the status of sulfur and oxygen, iron was und either in sulfides or in oxides, now pres- t either as pyrite or as hematite. Sulfurizing nditions were predominant at first, with an cumulation of pyrite; oxygen prevailed next, ith the formation of siliceous hematitic bodies. or that reason, hematitic jasper-like meta- ales, associated with pyrite deposits, are ost often found on their hanging wall side. ne change from sulfide ores to red hematitic ocks commonly occurs through a zone of ternating thin green schist with a sulfide crustation; and by red sulfide-free hema- te.

When the mineralized distillates, on their ay through solidified lavas, encountered ructurally and lithologically favorable rocks, lditional ore-making did occur, with the rmation of typical sub-volcanic pyrite ore eposits. Such are the ore lenses in the Vlasni- ikha and Skalistoye deposits in the Urup. hey differ from the main body not only in their osition in extrusive rocks, stratigraphically wer than the main body, but also in a normal ontact alteration of enclosing rocks on both des of the ore bodies.

The paths of mineralized volcanic distillates in the extrusive rocks are marked by numerous and extensive zones of lighter-colored and pyritic rocks.

The recurring volcanic acitvity in the period of formation of extrusive-sedimentary rocks could have led to a recurring liberation of intra- and post-volcanic ore-bearing emanations and to the formation of independent ore deposits corresponding to consecutive stages of volcanic activity. This is verified by ore bodies in various intervals of stratigraphic sections of the Urup, Beskes, and other pyrite deposits of the north Caucasus.

It follows from the above that in exploring for the most promising pyrite ore prospects in the north Caucasus, the following factors should be considered:

a — stratigraphic factors, i. e., the associa- tion of pyrite deposits with definite parts of volcanic sections, specifically with breaks in volcanic activity;

b — volcanic factors, i. e., the tendency of such deposits to occur near the centers of vol- canic activity;

c — geochemical factors expressed by lighter-colored and pyritic zones in volcanic rocks in the area of occurrence of pyrite deposits;

d — structural factors as expressed in the accumulation of some pyrite ores in primary volcanic-sedimentary troughs;

e — lithologic factors, determined by the paragenesis of pyrite deposits with beds and intercalations of sealing-wax red, siliceous, hematitic meta-shale and finely clastic, hema- tite-carrying tuff.

The study of geologic conditions of the for- mation of north Caucasian pyrite began much later than that of the Urals, the Altay, and other areas of the Soviet Union, and abroad. The data on hand are still very limited and the conclusions based on them are of a preliminary nature. Therefore, the considerations on the origin of some pyrite deposits in the north Caucasus, as set forth in this paper, are also tentative, requiring further study.

REFERENCES

1. Baranov, I. Ya., Mineralogiya i petrografiya paleozoyskikh metamorficheskikh formatsiy zony Peredovogo khrebta na Severo- Zapadnom Kavkaze [MINERALOGY AND PETROGRAPHY OF PALEOZOIC META- MORPHICS IN THE PEREDOVOY RANGE ZONE, NORTH CAUCASUS]: Uch. Zap.

Rostovsk. n/D. un-ta, t. 17, vyp. 4, 1952.

2. Zavaritskiy, A. N., O genezise kolchedannykh mestorozhdeniy [ON THE ORIGIN OF PYRITE DEPOSITS]: Izv. Akademiya Nauk SSSR, Ser. Geol., no. 3, 1943.

3. Zaridze, G. M., Proiskhozhdeniye granitoidov i ikh rudonosnost' na primere Kavkaza [THE ORIGIN OF GRANITOIDS AND THEIR ORES AS EXEMPLIFIED IN THE CAUCASUS]: Sov. Geologiya, no. 4, 1958.

4. Ivanov, N. V., O genezise kolchedannogo mestorozhdeniya na Severnom Kavkaze [THE ORIGIN OF A PYRITE DEPOSIT IN THE NORTH CAUCASUS]: Zap. Vses. Mineralog. Ob., ch. 82, no. 2, 1956.

5. Kurbanov, A. Sh., Geologiya, mineralogiya i vozrast rudnykh tel Urupskogo kolchedannogo mestorozhdeniya [GEOLOGY, MINERALOGY, AND THE AGE OF THE URUP PYRITE ORE BODIES]: Sb. Materialov po Geol. Tsvern., Redkikh i Blagorodn. Metallov, vyp. 2, 1958.

6. Netreba, A. V., O vozraste kolchedannogo orudneniya na Severo-Zapadnom Kavkaze [THE AGE OF PYRITE MINERALIZATION IN THE NORTHWEST CAUCASUS]: Izv. Akademiya Nauk SSSR, Ser. Geol. no. 3, 1959.

7. Smirnov, V. I. and T. Ya. Goncharova, O rudnykh gal'kakh v porodakh krovli Urupskogo mednokolchedannogo mestorozhdeniya na Severnom Kavkaze [ORE PEBBLES IN ROCKS OVERLYING THE URUP COPPER PYRITE DEPOSIT IN THE NORTH CAUCASUS]: Dokl. Akademiya Nauk SSSR, t. 126, no. 1, 1959.

8. Tuzikov, R. P., Nekotoryye cherty genezisa Urupskikh kolchedannykh mestorozhdeniy (Severnyy Kavkaz) [SOME FEATURES OF THE ORIGIN OF THE URUP PYRITE DEPOSITS (NORTH CAUCASUS)]: Izv. Akademiya Nauk SSSR, Ser. Geol., no. 5, 1959.

9. Shadlun, T. N., O nekotorykh metamorficheskikh teksturakh i strukturakh rud [SOME METAMORPHIC TEXTURES AND STRUCTURES OF ORES]: Ibid., no. 2, 1954.

Moscow State University

Received August 8, 1959

ASSIMILATION PHENOMENA AS ILLUSTRATED BY MINOR INTRUSIONS OF THE GYUMUSHKHANA COMPLEX, ARMENIA[1]

by

A. P. Lebedev and E. G. Malkhasyan

The petrograph of one of the minor intrusions of the Gyumushkhana complex, made up of monzonite with a gabbroid fringe and located in Eocene porphyrite is described. The authors explain the formation of basic rocks in the peripheral zone of the intrusion by processes of assimilation of basement rocks underlying the volcanics. These processes took place at a comparatively shallow depth (i. e., by "sub-volcanic assimilation").

* * * * *

The major role of assimilation processes in the petrogenesis of many minor intrusions in the Caucasian fold zone ("neointrusions") has often been noted, first of all by D. S. Belyankin, V. P. Yeremeyev, and others. At the same time, their views on assimilation, expressed in general terms, were as a rule seldom substantiated by a consideration of specific environments and conditions, despite the fact that these conditions could have been very different in each particular instance. An interesting example is one of the minor intrusions in the Gyumushkhana complex of Armenia, discussed in this paper. Detailed study affirms the substantial role played in its formation by processes of sub-volcanic or hypabyssal assimilation. This intrusion was briefly described by one of the authors of this paper in collaboration with V. N. Kotlyar [13]. The present paper goes into more detail on the petrography and petrogenesis of this interesting complex, on the basis of new data.

The Gyumuskhana group of intrusions is located on the left bank of the upper Arpa, within the Ambarial and Zivlikh area (Figure 1.). Individual outcrops may be seen northeast of Gndevaz village and near Akhkend point. First to study this extremely interesting intrusive group was V. N. Kotlyar [12] whose work is still valuable. Subsequent study was directed mostly for mineral prospecting and has contributed little to the petrographic data. Some new material was gathered by E. G. Malkhasyan in 1957.

The intrusive bodies are stock-like, extending over 1.5 km^2; in plan, they are round to elliptical. Their rocks are chiefly by monozonite, monzonite-diorite, and to a small extent by alkalic gabbros, olivine-orthoclase gabbro (kentallenites), and olivine essexite. These varieties usually change from one to another gradually, without sharp contacts.

The intrusive complex and the enclosing rocks are cut by dikes which are different at different places; they are diorite porphyyr and diabase dikes; and quartz, micropegmatite, and aplitic veins.

In the central part of the complex, corresponding to the Ambarial segment in the central part of the Zivlikh Range, there are minor intrusions having a complex structure, formed by monzonite changing along the periphery to more and more basic rocks carrying plagioclase, augite, biotite, and olivine, usually with a sulfide incrustation. In composition, these rocks correspond to syenite and monzonitediorite, alkalic and olivine-orthoclase gabbro, and essexite. These intrusive rocks, chiefly from the Zivlikh stock (Figure 2), are described in detail, below.

MONZONITES AND SYENITES

Monzonite rocks are distributed chiefly in the Ambarial area and in the central part of the Zivlikh Range. They are gray-green, medium- to coarse-grained (Figure 3). Their structure is monzonitic to hypidiomorphic-granular. Their mineral composition is plagioclase (andesine), orthoclase, augite, biotite, apatite, magnetite. Secondary minerals are chlorite, epidote, sericite, calcite, and biotite.

---

[1]Yavleniya assimilatsii na primere malykh intruziy Gyumushkhanskogo kompleksa v Armenii.

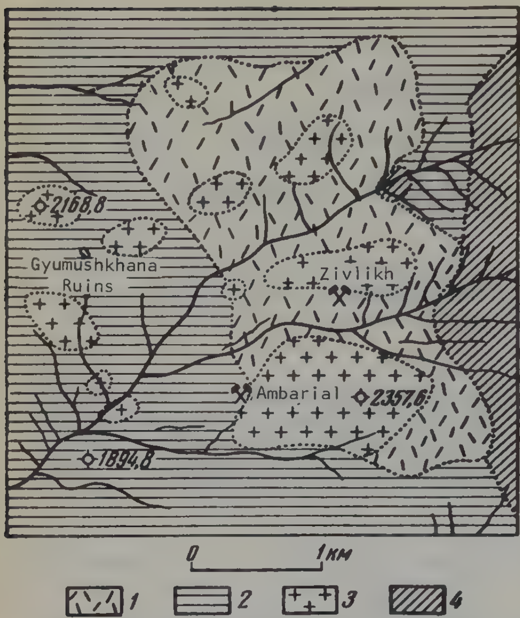

FIGURE 1. Generalized map of distribution of the Gyumushkhana intrusive group.

1 -- Middle Eocene pyroxene and hornblende andesite; 2 -- Middle Eocene tuffaceous sequence (tuffite, tuffaceous sandstone and conglomerate; 3 -- intrusions of the Gyumushkhana complex; 4 -- hydrothermally altered alunitized and quartzitic rocks.

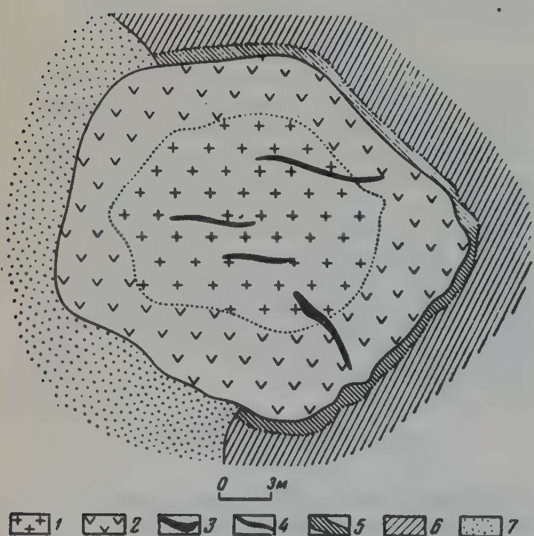

FIGURE 2. Generalized map of the Zivlikh intrusive body.

1 -- granitoid rocks; 2 -- gabbroids; 3 -- anorthosite; 4 -- granophyre; 5 -- hornblende rock; 6 -- andesite; 7 -- tuffite.

The plagioclase (36% of rock)[2] andesine (39% An, $D\gamma = 51°$, $D\alpha = 42°$, $D\beta = 74°$) and shows crystals twinned "on prism."

This mineral has well-defined crystals, idiomorphic with relation to K-feldspar. As a result of decomposition of plagioclase, chlorite, sericite, and calcite have been formed in some crystals.

K-Na-feldspar (35% of rock) is represented by xenomorphic crystals, up to 1.5 mm. Angle $\perp$ (001) $\beta = 9°$; 2V ranges from -48 to -64°; $\gamma - \alpha = 0.006$. Cleavage is very poorly expressed along (010). Judging from these constants, the mineral is triclinic and is anorthosite.

Augite (about 10% of rock) is generally light-colored in thin sections, ranging from colorless to light green. The crystals are up 2.5 to 3 mm, in coarse-grained varieties. The mineral shows twinning along (100), seldom along (001); $\gamma - \alpha = 0.025$; $+2V = 57°$; $c\gamma = 45$-$49°$. Chloritization has been observed in many crystals, with individual crystals fully turned to chlorite; secondary biotite is developed in places in fractures. Some thin sections exhibit pyroxene of two generations, with the same optical properties, except that the first generation mineral has $c\gamma = 40°$ and $+2V = 60°$, which corresponds to diopside.

Biotite (18 to 30% of rock) is represented by short tabular, brown, strongly pleochroic crystals, up 1.2 to 1.6 mm. In some crystals, it is a greenish variety hardly distinguishable from the primary brown biotite in optical constants. Chlorite is the end product of the biotite decomposition.

Apatite forms elongated grains, up to 0.8 mm long. $\gamma - \alpha = 0.005$.

The ore mineral is magnetite which has an irregular isometric form in thin section.

Secondary minerals, e.g., chlorite, epidote, sericite, calcite, and biotite, are especially abundant in strongly altered rocks.

Chlorite is drab green, with a low birefringence $\gamma - \alpha = 0.005$. It is biaxial and negative. As a rule, it forms radial aggregates. It is formed as a product of decomposition of biotite and pyroxene and of a partial replacement of plagioclase.

Epidote is a product of decomposition of pyroxene and plagioclase. It is greenish, with

---

[2]These and subsequent quantitative figures on minerals composition refer to rocks from the Zavlikh stock.

FIGURE 3. Monzonite. The Zivlikh Range. Specimen No. 94, in ore; natural size.

$\gamma - \alpha = 0.030$ ($\gamma - \alpha = 0.003$?).

Sericite is formed on plagioclase and occurs only in isolated thin sections.

Calcite, is subordinate in thin section, being developed on feldspars.

Biotite has been observed only in isolated thin sections where it occurs in fractures in pyroxene as a decomposition product of the latter.

The order of crystallization of minerals (on the basis of relative idiomorphism) is as follows: 1) magnetite 2) apatite 3) pyroxene 4) biotite 5) plagioclase 6) orthoclase. Present among secondary minerals are chlorite, epidote, sericite, calcite, and green biotite.

The chemical characteristics of these monzonite rocks is given in Table 1, analysis 1.

Quartz syenite is a medium- to fine-grained leucocratic rock, with a panidiomorphic texture, consisting chiefly (85 to 90%) of idiomorphic tabular crystals of anorthoclase; dispersed among them are small xenomorphic bodies of clinopyroxene, commonly edidotic, also pocket-like formations of quartz, in places in small geodes; also geodes of zoicite and quartzite, locally carrying sulfides.

OLIVINE-BIOTITE-ORTHOCLASE LEUCOGABBRO

A generalized description of alkalic olivine-orthoclase leucocratic gabbro and olivine essexite and kentallite is given in this section. These rocks constitute a single continuous series of gabbroid rocks which form the peripheral parts of the Zivlikh stock and some other bodies. They all are similar in mineral composition, except for quantitative differences in mineral ratios.

Macroscopically, they are gray-green to black rocks, medium fine grained. They consist of plagioclase (labradorite), monoclinic pyroxene, olivine, K-feldspar, biotite, hornblende, apatite, and magnetite. Plagioclase is predominate (Figures 4, 5) determining the over-all leucocratic aspect of the rock.

Table 1

Chemical soil analyses of the Gyumushkhan complex

Rock	Monzonite	Gabbroids			Andesite porphyrite	Anorthosite
	analysis 1	analysis 2	analysis 3	analysis 4	analysis 5	analysis 6
SiO_2	53.46	48.40	49.71	50.88	56.80	52.14
TiO_2	0.92	1.00	1.30	1.34	1.22	1.35
Al_2O_3	18.28	24.09	18.32	19.35	19.50	25.99
Fe_2O	4.35	10.41	3.97	4.32	4.87	3.99
FeO	4.27		2.85	2.60	6.06	1.48
MgO	2.95	1.26	3.86	3.46	2.35	1.88
CaO	7.38	9.96	9.96	10.08	3.71	8.68
MnO	0.26	0.15	0.18		0.18	0.07
Na_2O	3.57	3.25	4.25	3.72	3.36	3.04
K_2O	3.42	2.15	3.12	3.35	0.96	1.20
Losses in heating	1.22	—	—	—	1.04	2.22
H_2O	—	—	0.07	1.12	0.13	—
Total	100.08	100,07	99.72	100.22	100.18	100.14
Analyst or bibliographic reference	A. K. Ivanyan Armgeolupr	G. M. Dzrbashan, IGN ArmSSR		V. N. Kotlyar [12]	S. Dekhtrikyan IGN AN ArmSSR	A. A. Petrosyan, IGN AN ArmSSR

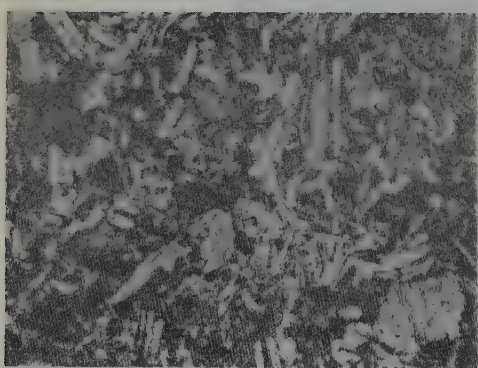

FIGURE 4. Leucocratic gabbro. 50x; Nicols crossed.

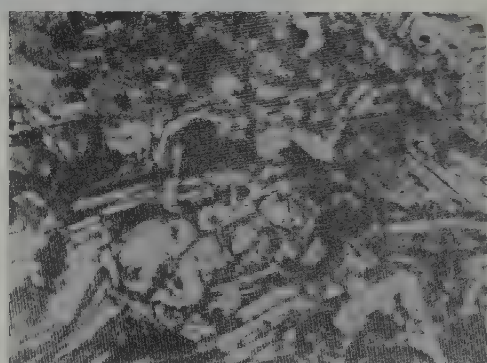

FIGURE 5. Olivine leucocratic essexite. 50x; Nicols crossed.

The texture is gabbro-ophitic to hypidiomorphic-granular.

Plagioclase is represented by fresh-looking tabular crystals, up to 2 mm long. Its grain show in places more or less idiomorphic outlines; more commonly they are allotriomorphic. The irregularity of plagioclase outlines apparently is partly due also to resorption corrosion.

Plagioclase exhibits a clean-cut twinning according to the albite, Carlsbad, and other rules ($D\alpha = 35°$ ($D\gamma$?) $D\beta = 63.5°$; $D\alpha = 69°$; $P\gamma = 35°$; $P\beta = 69°$; $P\alpha = 63.5°$ and $D\gamma = 60°$; $D\beta = 72°$; $D\alpha = 35°$), which corresponds to labradorite (62 to 64% An).

Plagioclase crystals are usually fresh, without appreciable signs of secondary alteration. In places, they contain small inclusions of apatite, olivine, monoclinic pyroxene, and ore minerals. Some plagioclase crystals show a weak zonation; locally they form antiperthitic growths with orthoclase.

Monoclinic pyroxene is developed in two generations. Colorless coarse crystals up to

mm is probably diallage; varieties with regular outlines are allotriomorphic with lation to plagioclase. This mineral shows ell defined cleavage along (100) and exnction $c\gamma = 44$ to $46°$; $+2V = 59$ to $60°$; γ - = 0.025.

Diopside has been observed in places in clusions in diallage. Its optical constants e: $c\gamma = 40$ to $42°$; $2V = +55°$; $\gamma - \alpha = 0.027$. his indicates its lower iron content compared ith diallage.

Along the periphery and the cleavage planes, roxene is locally replaced by uralite hornende which in turn is replaced by biotite d chlorite. It should be noted that the edges diallage grains show a very interesting deelopment of some acicular mineral with a w birefringence and positive elongation. Beuse of the very small size of the needles, it uld not be identified.

Olivine (up to 15% in most melanocratic embers of the complex) forms grains up to 8 mm in diameter, idiomorphic with retion to plagioclase and pyroxene; they rarely ow regular crystallographic outlines. As a le, the mineral has been considerably corded in the crystallization of the melt.

The olivine grains are broken up by a sysm of irregular fractures, with chlorite and erpentine developed along them; $\gamma - \alpha = 0.036$; $V = 78$ to $86°$, which corresponds to hyalosierite Fa_{24-34}. They carry small inclusions f apatite and magnetite and are hemmed in aces by a thin reaction film of hornblende.

Anorthoclase is represented by grains learly xenomorphic with relation to plagioase and pyroxene and filling the interstices etween them. Angle $\perp$ (001), $\beta = 6$ to $8°$, (-) $V = 43°$, suggesting anorthoclase. $\gamma - \alpha =$ .006. Individual grains of K-feldspar have a icroperthitic texture expressed in a multitude f worm-like inclusions of acid plagioclase. he cleavage is poorly defined.

There are inclusions of plagioclase and ther, earlier precipitated minerals.

Biotite forms scale-like plates, up to 1.5 m long. They show strong pleochroism om dark-brown along γ to light-brown along . Biotite commonly forms inclusions in rystals of plagioclase and K-feldspar.

Hornblende is represented by two types: rimary hornblende (not over 1% of total rock), rystallized out of the magmatic melt; and econdary uralite, developed on pyroxene. he primary hornblende forms thin reaction inges about some olivine grains. $\gamma - \alpha$ of e mineral is 0.019 to 0.021; $c\gamma = 21°$; pleohroism from drab green along α to yellow-green along γ, and green along β.

Apatite and magnetite are considerably developed among accessory minerals.

Apatite is represented by both fine and large, up to 1 mm elongated grains, idiomorphic prismatic in habit, with typical hexagonal sections; it is usually colorless in thin section.

Magnetite forms considerable irregular accumulations in some thin sections.

Chlorite is most commonly developed on olivine, less commonly on pyroxene and secondary hornblende. Usually, it occurs in fine pale-green leaflets and scales.

Uralite is developed along the periphery and fractures of pyroxene grains, replacing the latter. In its turn, uralite hornblende is replaced by biotite, chlorite, and calcite.

Calcite forms rare irregular bodies and replaces nearly all other minerals.

The character of crystallization and the order of mineral precipitation (on the basis of relative idiomorphism) is as follows: accessory minerals (ore mineral and apatite) crystallize first, followed by olivine, diopside, diallage, plagioclase, hornblende, biotite, and K-feldspar.

The chemical characteristics of these rocks is given in Table 1, analyses 2, 3, and 4.

ROCKS OCCURRING IN LENSES AND SCHLIEREN

Anorthosites make up schlieren- or veinlike bodies, up to 5 m long and up to 1 m thick, located in the central and intermediate (between center and periphery) parts of the Zivlikh intrusion. Externally, they are more or less light colored, medium to fine grained (1 to 2.5 mm) rocks, mostly with a panidiomorphic trachytoid texture, with a definite orientation of crystals (Figure 6). The plagioclase laminae (leists) are of about the same length; scattered among them are short prismatic sub-ikiomorphic crystals of clinopyroxene (up 5 to 8%), with the interstices filled with minerals of a late igneous or autometasomatic complex, e.g., epidote, biotite, actinolite, chlorite, sericite, serpentine.

Plagioclase is represented by an almost nonzoned labradorite (extinction angle in zone $\perp$ RM is 32 to 34°) and is extensively replaced by paragonite and zoisite. Clinopyroxene forms aggregates of irregular, fine grains and exhibits a pale greenish color. Gradual transitions have been observed between syenite and

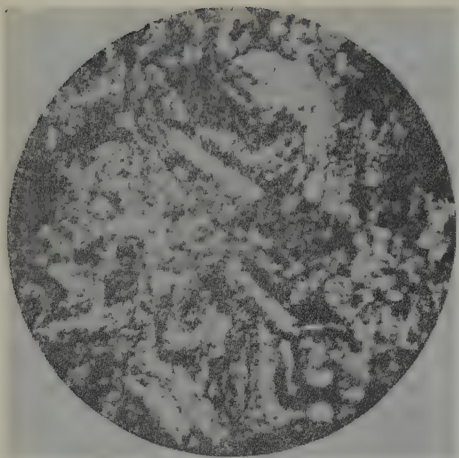

FIGURE 6. Anorthosite. 64x; Nicols crossed.

anorthosite in the contact with the syenite-monzonite facies of the central part of the Zivlikha intrusion. In anorthosites, irregular bodies of epidote and quartz appear in interstices of the plagioclase laminae (leists); syenite, on the other hand, becomes enriched in small plagioclase crystals growing in interstices between microcline grains. The chemical composition of anorthosite is given in Table 1, analysis 6.

Like anorthosite, granphyres form lenses and schlieren-like bodies in gabbro-syenite of the Zivlikh massif. Seen in thin section (Figure 7) is an aggregate of micropegmatitic growths of quartz and anorthosite, with local spherulites of pure K-feldspar and a totally decomposed basic (?) plagioclase. The rock is rich in quartz which fills the interstices.

CONTACT AND HYDROTHERMAL ACTION OF THE INTRUSIONS

The contact effect of the Gyumushkhana intrusives on the enclosing rocks was fairly strong and leads to the appearance of the following: a) quartz-feldspar and feldspar hornfels; b) secondary quartzite; and c) alunite.

Hornfels originates in the action of a monzonite magma on the enclosing volcanic rocks, andesite and tuffite. The contact halos, represented by hornfels, are traceable in a band, locally up to 60 m wide. These recrystallized, dark, fine-grained rocks belong to quartz-feldspathic and feldspathic hornfels.

The hornfels is mostly allotriomorphic; hornfels away from the contact is blastoporphyritic with porphyroblasts of plagioclase. Its mineral components are plagioclase (andesine, labradorite), monoclinic pyroxene (diopside, augite), orthoclase (in small amounts), hornblende, and tourmaline (only in the immediate contact zone). Some isolated grains carry magnetite, apatite, and garnet (1 to 3 grains per thin section).

Secondary quartzite makes up the area as far as the Zangezur Range water divide, the Kysyr-Dag Mountain. According to V. N. Kotlyar [12], these rocks were formed as a result of the activity of post-magmatic solutions which originated in the intrusive magma itself and were activated by the assorted compounds they carried along, including silica. Probably connected with the action of the same solutions was the alunitization widely developed on the western slope of the Kysyr-Dag and in the Zivlikh Range.

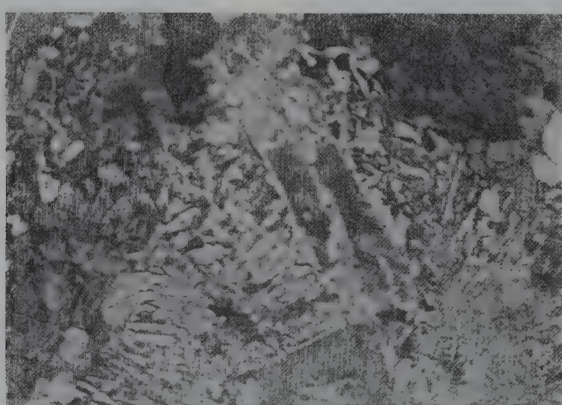

FIGURE 7. Granophyre. 160x; Nicols crossed.

PROBLEMS IN PETROGENESIS

From the above data it appears that the Zivlikh intrusion (as well as the other intrusions of this group) is characterized by its complex petrographic composition, with the presence of two rock series (not counting the schlieren and vein rocks): 1) monzonite-syenite and 2) leucogabbro-essexite-kentallenite).

Such a complexity in composition, present as it is in a comparatively small volume of rock, is characteristic of many other minor intrusions, as well, similar to ours in form, dimensions, and geologic position. Especially characteristic in this respect are Mesozoic and Tertiary "neointrusions" widely developed within the Caucasian fold belt.

Thus, according to G. R. Chkhotua [19], small circular intrusions are common in the Jurassic of Abkhaziya. They are made up of monzonite and gabbro (with up to 15% olivine) closely connected with transitions, and locally changing to anorthosite. In the Gubadzeul basin, a young intrusion, 2 x 1 km, in Eocene tuffaceous porphyrite, is made up of diversified rocks – from quartz syenite to monzonite and diorite [17].

In Adzhariya, a small intrusion in Mesozoic porphyrite along Khala-Tskahali River consists of gabbro-syenite in the center, and of gabbro along the periphery; all these rocks are cut by aplite veins. The gabbro, according to V. P. Yeremeyev [6], is of an assimilation origin. The neighboring Dzhoga intrusion is of a similar structure.

In the Abakur neointrusions (Svanetiya), too, there is a close association of intermediate and basic rocks, from diorite to gabbro and pyroxenite (in patches within the gabbro). The gabbroids are marked by their high calcium content [7]. Similar compositional features have been noted by Sh. A. Azizbekov for some minor intrusions in Azerbaydzhan [2]. The Khevisdzhvar neointrusion (the Dzirul' massif in Georgia) is made up of acid banatite, in its central part, and of monzonite and diorites along the periphery [10].

Expressed more or less definitely in all of these intrusions penetrating porphyritic rocks is the increase in basicity from the center to the periphery – toward the contact. This regularity is common in small as well as larger intrusions. According to D. S. Belyankin et al [3], the smaller the intrusion, the more basic its composition, on the whole.

From the examples cited, the number of which could be considerably multiplied, it is reasonable to conclude that, in petrographic composition (intermediate to basic) and in structure, the Zivlikh and other intrusions of the Gyumushkhana group belong to the most common type (in the Caucasian fold zone) of heterogenous minor intrusions of a gabbro-monzonite composition, with their basicity rising toward the periphery. Most authors ascribe this structure to the assimilation phenomena, without giving, however, any more or less detailed description of the mechanism involved in any particular example.

Different explanations can be advanced for the structure of the Zivlikh and similar intrusions.

First, it can be assumed that both rock series, the intermediate and the basic, belong to two different intrusive phases, i. e., they were related to the intrusion of two independent magmatic melts, of an intermediate and a basic composition, arising from depths in a definite sequence.

From this point of view, the Zivlikh intrusion can be compared to annular conic intrusions, which occur, e. g., on the Island of Mull in England and in other places. The absence of sharp intrusive contacts between rocks of different facies, the absence of tempering, brecciation, and interpenetration are against such an assumption, however; in addition, there is the presence of gradual transitions between rocks of all series. It also is hardly probable that such small intrusions were formed by differential intrusion of two kinds of magma originating from sources different in composition yet very near each other.

The phenomena observed are equally difficult to explain by differentiation of a magma in situ, at the place of its cooling. On one hand, this would contradict the above-mentioned evidence of a blastic growth of minerals and the general unevenness of structures and textures in the gabbroid series – both a clear evidence of hybrid formations; on the other hand, the spatial relation of rocks in a massif, too, is obviously out of accord with the concept of gravity fractionation and similar processes.

Accordingly, one must turn for an explanation to the assimilation concept. Such was the general view on the Gyumushkhana intrusions held by one of the authors of this paper (E. G. Malkahasyan) and V. N. Kotlyar in his 1957 work [13]. They believed that the gabbroid varieties of rocks of this complex originated as a result of assimilation of the enclosing Eocene volcanics by a granitoid magma. This is corroborated, in their opinion, by the abundance of xenoliths in peripheral parts of the intrusions. The formation of complex Caucasian neointrusions is ascribed to assimilation also by D. S. Belyankin and other authors.

In fair accord with the assimilation concept

are a number of the above-mentioned features of these intrusions, such as the association of gabbroids with the contact, the lack of stability in the structure, texture, and mineral composition, as well as other features generally typical of hybrid formation [1, 9].

At the same time, a more detailed study of material on the Gyumushkhana intrusive group shows that the petrologic and spatial relations of their rocks are unexplainable solely by the direct effect of magma on the contacting rocks; the solution to the problem is much more complicated.

A study of the composition and structure of rocks of the two series, the intermediate and the basic, reveals the following features.

Rocks of the first series (monzonite-syenite) generally do not differ in composition from normal igneous rocks of an alkalic magma. There are some differences, such as the slightly higher lime content and certain variability in mineral composition.

magnesium content; by the evidence of resorption of plagioclase; and by the local appearance of blastic structures. Rocks of this series make up only a narrow peripheral band, 2 to 5 m wide, outlining the monzonite body. Such a characteristic occurrence, at the contact, along with the abundance of xenoliths of the enclosing rocks (andesitic porphyrite), indeed appear to suggest the formation of the second series rocks by a direct assimilation of porphyrite by the monzonite magma. This, however, is contradicted by some facts.

First of all, it appears from Table 1 and the diagram in Figure 9, that the chemical composition of gabbroids is not intermediate between the composition of "lateral" andesite and the monzonite from the central part of the intrusion. Generally speaking, these monzonites and andesites are very different in composition. The gabbroid series rocks (see Table 1) differ from monzonites and andesites by their dificiency in Si, and in the high content of Al, Mg, and Fe, and to a smaller extent of Ca (the latter only as compared with

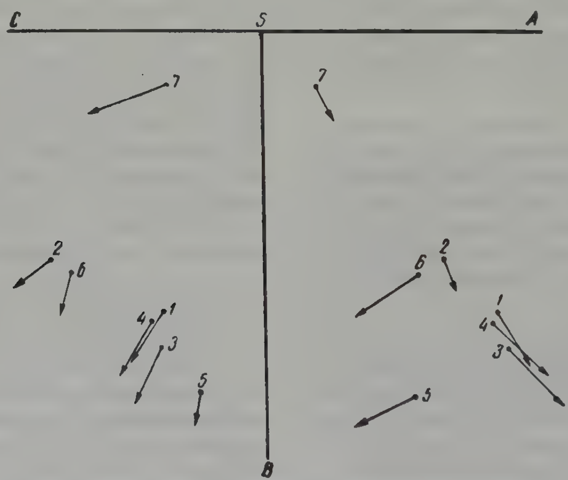

FIGURE 8. Diagram of numerical characteristics of rocks from the Zivlikh intrusion; after A. N. Zavaritskiy.
The vector figures correspond to the analysis numbers in Table 1.

Rocks of the second series (leucogabbro-essexite-kentallenite) cannot be assigned to the normal magmatic series, because of their structural and textural instability and because of their peculiar chemical composition. They are characterized by inconsistent mineral ratios, by an occasional simultaneous presence of granophyre and olivine; by the greater importance of alkalies, especially of sodium and calcium, (Figure 8), by a lower iron and

monzonite). Only in their alkalie content do the gabbroids occupy an intermediate position between monzonites richer in alkalies and andesites poorer in them.

On the whole, then, the monzonite and andesite are almost identical in composition, save for the small deficiency in alkalies, magnesium, and calcium in the latter.

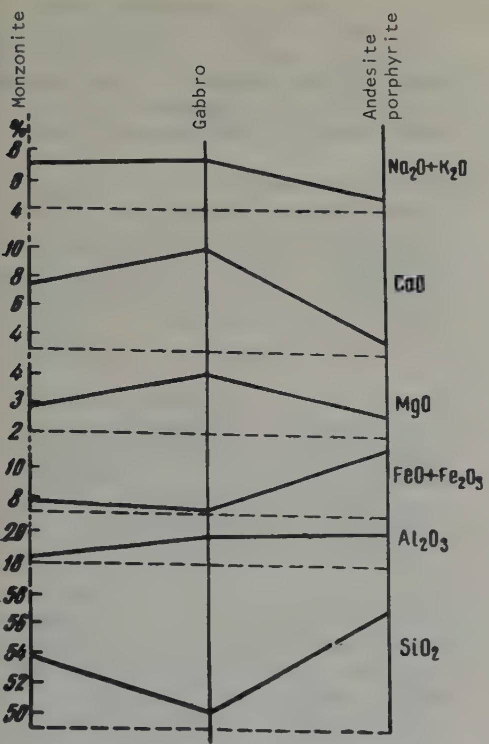

FIGURE 9. Diagram of content of individual oxides in rocks of the Zivlikh intrusion and in the enclosing rock.

An assumption to the effect that gabbroid rocks of the peripheral zone were formed by a monzonite magma which reworked andesite rocks would imply an addition from the magma not only of alkalies and calcium but of such components as iron and magnesium, as well. While the calcium and magnesium addition is substantiated by the presence of newly formed granophyre, biotite, and amphibole in gabbroids, there is no evidence of any addition of iron and magnesium; furthermore, neither the olivine nor the pyroxene carry any signs of a blastic origin.

Thus the presence in the gabbroids of such minerals as olivine and pyroxene cannot be explained here by an addition of iron and magnesium, either from the enclosing andesite nor from the monzonite magma itself (because both are poorer in these components than the gabbroids). Consequently, it must be assumed that, despite the number of obvious criteria indicating a hybrid origin of these rocks, it cannot be explained by assimilation processes in situ.

It is most probable that at a certain definite stage of crystallization of this intrusive body, there existed a sharply differentiated melt, previously contaminated by more basic material at a greater depth. Segments of such a contaminated or anatexic magma of a gabbroid composition should have originated most likely at a shallow depth (inasmuch as the composition of this anatexic solution remained unequalized), through fusing of rocks more basic than the near-contact andesite. The possibility of a partial assimilation of limestone is not excluded, inasmuch as there are examples of the appearance of a basic, almost pyroxenitic composition in rocks, resulting from interaction of an acid magma and limestones (for example, as described for the Pyrenees by A. Lacroix [20], etc.). In the further course of events, the juvenile (monzonitic) and the anatexic (gabbroid) portions of the melt crystallized simultaneously and parallel to each other, partially penetrating each other by diffusion. Judging from the incomplete equalization (homogenization) of the anatexic gabbroid magma, the contamination took place at a comparatively shallow depth.

It can be assumed that the main transformation factor probably was not the higher temperature of the magma, alone, but the abundance of volatiles in it (as witness its activity at the contacts). The presence of anorthosite schlieren in the intrusion is probably also due to the effect and the further evolution of the anatexic melt. According to T. M. Dembo [5], in the differentiation of the liquid phase in an anatexic magma, subsequent crystallization may lead to the formation of a monomineral rock, such as anorthosite, which is indeed confirmed in our study.

Thus, the origin of hybrid rocks under consideration and the formation of an anatexic gabbroid magma are related to processes of "sub-volcanic assimilation" which take place during the rising of a magma through zones of intensive folding, at comparatively shallow levels, in the formation zone of minor intrusions and near-surface hearths. Although, generally speaking, the intensity of the assimilation processes grows with depth [1, 11, 18], under especially favorable tectonic conditions and with an abundance of volatiles, a magma may acquire a considerable assimilative capacity, even under hypabyssal conditions. This is also corroborated by the assimilation phenomena under the platform conditions of igneous activity [14].

It appears, then, that in the nature of their assimilation processes, these complex intrusions of the Gyumushkhana group differ somewhat from a number of other Caucasian neointrusions of similar composition whose origin is explained by direct hybridization, during the cooling-off site. It should be understood however, that the true picture of assimilation phenomena in many other intrusions is considerably more complicated and will require

a more painstaking and comprehensive analysis of composition and structure.

REFERENCES

1. Abdulayev, Kh. M., Geneticheskaya svyaz' orudneniya s granitoidnymi intruziyami [GENETIC RELATIONSHIP BETWEEN MINERALIZATION AND GRANITOID INTRUSIONS]. Gosgeoltekhizdat, 1954.

2. Azizbekov, Sh. A., Geologiya i petrografiya severo-vostochnoy chasti Malogo Kavkaza. [GEOLOGY AND PETROGRAPHY OF THE NORTHWEST PART OF LITTLE CAUCASUS]. Izd. AN AzerbSSR, 1947.

3. Belyankin, D. S., K voprosu o neointruziyakh Tsentral'nogo Kavkaza. [THE PROBLEM OF CENTRAL CAUCASIAN NEOINTRUSIONS]. Izv. AN SSSR, Ser. Geol., No. 2, 1939.

4. Belyankin, D. S., K voprosu o petrogeneticheskom znachenii kontaktnykh yavleniy. [PETROGRAPHIC SIGNIFICANCE OF CONTACT PHENOMENA]. Tr. XVII Sess. Mezhdun. Geol. Kongr., t. 5, 1937.

5. Dembo, T. M., Yavleniya anateksisa, gibridizma i assimilyatsii kaledonskoy granodioritovoy intruzii severnoy chasti Kuznetskogo Alatau. [PHENOMENA OF ANATEXIS, HYBRIDIAM, AND ASSIMILATION IN A CALEDONIAN GRANODIORITE INTRUSION IN THE NORTHERN PART OF KUZNETSK ALATAU]. Sov. Geol., sb. 51, 1956.

6. Yeremeyev, V. P., Dopolnitel'nyye dannyye k izucheniyu neointruziy Adzharii. [NEW DATA ON NEOINTRUSIONS OF ADZHARIYA]. Tr. Inst. Geol. Nauk AN SSSR, vyp. 89, 1948.

7. Yeremeyev, V. P. and V. P. Petrov, Neointruzii Svanetii. [NEOINTRUSIONS OF SVANETIYA]. In book, Verkhnyaya Svanetiya i Prileg. Chasti Abkhazii, ch 2, Izd. AN SSSR, 1940.

8. Yeremeyev, V. P. and V. P. Petrov, Petrograficheskoye opisaniye neointruziy v baseyne Kodora. [PETROGRAPHIC DESCRIPTION OF NEOINTRUSIONS IN THE KODOR BASIN]. Ibid.

9. Zavaritskiy, A. N., Petrografiya Berdyaushskogo plutona. [PETROGRAPHY OF THE BERDYAUSH PLUTONIC BODY]. Ob'yed. Nauch. Tekhn. Izd., 1938.

10. Zaridze, G. M., Zakonomernosti razvitiya vulkanizma v Gruzii i svyazannyye s nimi rudoproyavleniya. [REGULARITIES IN THE DEVELOPMENT OF VOLCANISM IN GEORGIA AND ASSOCIATED ORE SHOWINGS]. Izd. AN GruzSSR, 1947.

11. Koptev-Dvornikov, V. S., Yavleniya gibridizatsii na primerakh nekotorykh granitnykh intruziy paleozoya Tsentr. Kazakhstana. [HYBRIDISM PHENOMENA AS DEMONSTRATED ON SOME GRANITE INTRUSIONS IN THE PALEOZOIC OF CENTRAL KAZAKHSTAN]. Tr. Inst. Geol. Nauk AN SSSR, vyp. 148, 1953.

12. Kotlyar, V. N., Geologicheskiy ocherk vostochnoy chasti Daralegezskogo uyezda v Armenii. [GEOLOGIC OUTLINE OF THE EAST OF THE DARALAGEZSKIY UYEZD (DISTRICT) IN ARMENIA]. Mater. po Obshch. i prikl. geol., vyp. 136, 1930.

13. Kotlyar, V. N. and E. G. Malkhasyan, Anortozity, granofiry i esseksitovyye porody Gyumushkhanskogo intruzivnogo kompleksa. [ANORTHOSITE, GRANOPHYRE, AND ESSEXITE OF THE GYUMUSHKHANA INTRUSIVE COMPLEX]. Dokl. AN ArmSSR, t. 24, No. 1, 1957.

14. Lebedev, A. P., Yavleniya gibridizma i assimilyatsii i ikh rol' v platformennom magmatizme. [PHENOMENA OF HYBRIDISM AND ASSIMILATION AND THEIR ROLE IN PLATFORM IGNEOUS ACTIVITY]. In book, Materialy k II Vses. Petrogr. Soveshch., 1958.

15. Levinson-Lessing, F. Yu., Uspekhi petrografii v Rossii. [PROGRESS OF PETROGRAPHY IN RUSSIA]. Izbr. Trudy, t. 2. Izd. AN SSSR, 1950.

16. Malkhasyan, E. G., K voprosu o vozraste Daralagezskikh intruzivov v Armenii. [AGE OF THE DARALAGEZ INTRUSIVES IN ARMENIA]. Byul. Mosk. o-va. Ispyt. Prir. Otd. Geol., t. 27, No. 3, 1952.

17. Nadiradze, V. R. and T. G. Kazkhashvili, Zotskaya neointruziya. [THE ZOTSK NEOINTRUSION]. Tr. Gruz. Polit. Inst., No. 3, 1955.

18. Khamrabayev, I. Kh., Magmatizm i postmagmaticheskiye protsessy v Zapadnom Uzbekistane. [IGNEOUS ACTIVITY AND POST-IGNEOUS PROCESSES IN WESTERN UZBEKISTAN]. Izd. AN UzSSR, 1958.

19. Chkhotua, G. R., Intruzivy Abkhazii. [INTRUSIVES OF ABKHAZIYA]. Tr. Gruz.

Geol. Upr., vyp. 2, 1941.

20. Lacroix, A., Les granites des Pyrenees et ses phenomenes de contacte. Bull. Serv. carte geol. Fr., vol. 10, 1898.

Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, Academy of Sciences, U.S.S.R., Moscow

Received, June 10, 1959

ABSOLUTE AGE OF EXTRUSIVE ROCKS IN THE MAGADAN BATHOLITH [1,2]

by

L. V. Firsov

In undertaking, during 1958, a systematic determination of the absolute age of extensive rocks in the northeastern part of the U. S. S. R., by the K-Ar method, we turned first to a case where geology was known to such an extent as to preclude any ambiguity in interpretation. Such a case was provided by the multiphase and multifacies Magadan batholith exposed on the coast of Tauysk inlet, in the vicinity of Magadan. The results of the absolute-age determination not only confirmed the geologic views on the time of formation of this batholith, but have demonstrated the applicability of the K-Ar method to absolute dating of late Mesozoic extrusive rocks.

GEOLOGIC SITUATION

The Magadan batholith is one of many granitoid intrusives of the Okhotsk-Chaun volcanic arc. The volcanic complex is represented here by rocks ranging from gabbro to alaskite and sub-alkalic granite, with granodiorite and granite the most common. Gabbros, gabbro-diorite, and quartz diorite, on one hand, and sub-alkalic and alkalic rocks on the other are very limited in development; nevertheless, they are typical of the complex as a whole. Ye. K. Ustiyev [6] calls this complex the Okhotsk.

Many of the intrusive massifs of the Okhotsk complex are not only petrographically heterogeneous but multiphase in different segments (heterogeneous and polygenetic intrusions of Ye. K. Ustiyev [7]). Their age and the age of the Okhotsk complex rocks as a whole are reliably determined by the relation of granitoids to sedimentary and volcanic formations. The extrusive rocks cut Upper Permian, Triassic, Lower and Middle Jurassic sedimentary rocks and are found to have complex relations with Lower and Upper Cretaceous volcanics and sedimentary rocks, reliably dated by numerous index fossils. Some of the earliest members of the complex are overlain by Upper Cretaceous lavas, while the last of the granitoids cut these lavas. Pebbles of the Okhotsk granitoids are present in fresh-water continental conglomerate with a Late Cretaceous flora [8].

On the basis of all available geologic data, Ye. K. Ustiyev compiled the following time sequence for these formations (Table 1).

The Ye. K. Ustiyev table is applicable not only to igneous formations of the Okhotsk-Chaunsk arc but also to the structurally and compositionally similar igneous formations among intrusives of the Yano-Kolyma belt of late Mesozoic folding.

STRUCTURE OF THE MAGADAN BATHOLITH

The Magadan batholith presents a body of 40 x 55 km; a portion of it lies under the water of the Tauysk inlet. The batholith is fringed in the north and east by Lower Cretaceous volcanics which it cuts, and by Upper Cretaceous lavas whose relationship with the granitoids has not been established. Remmants of an Upper Cretaceous porphyritic cover are present in different areas of the batholith at elevations of 200 to 500 m above sea level, thus suggesting some erosion has occurred. Its depth of formation should have been not over 1 km, if the probable thickness of Lower Cretaceous extrusives is taken into consideration.

It is not impossible that the Magadan

[1]Absolyutnyy vozrast izverzhennykh porod Magadanskogo batolita.

[2]Paper read at the 8th Session of Commission on the absolute Age Determination of Geologic Formation, Academy Sciences, U.S.S., May 22, 1959.

Table 1

Time Sequence for Intrusive and Extrusive Formations of the Okhotsk--Chaunsk Volcanic Arc, after Ye. K. Ustiyev

Time	Igneous activity	Cycles
Quaternary and Neogene	Land flows of basalt and acid volcanic ash	Tertiary-Quaternary
Paleogene	Land flows of basalt and andesite-basalt; intrusions of gabbro, diorite, and granite (?)	
Late Cretaceous	2. Intrusions of granite, chiefly sub-alkalic and alkalic	Upper Cretaceous
Early Cretaceous	1. Land flows of dacite and liparite lavas and some andesite	
	2. Intrusions of the Okhotsk granitoids, chiefly granodiorite	Lower Cretaceous
Late Jurassic	1. Land and some submarine flows of andesite and liparite	Upper Jurassic
	Granitoid intrusions, chiefly microcline granite	

batholith (as well as a number of other intrusives of the Okhotsk system) is an interformational body like a giant sphenolith with typical Suess batholithic features. The injection of magma appears to have taken place between Triassic and Jurassic sedimentary rocks; an undisturbed blanket of Lower Cretaceous extrusives with Upper Jurassic extrusives is also present Large areas of xeonogenetic textures, migmatized areas of earlier phase rocks, and a petrographic diversity are characteristic of the batholith.

According to A. M. Demin's study [2, 4], confirmed by observations of our own and of others, the sequence of formation of the batholith occurred as indicated in Table 2 The geologic dating is based on analogies with adjacent intrusions of the Okhotsk system. As such, it is not quite reliable, although the association of the batholithic intrusives with Lower Cretaceous and in part with Upper Cretaceous rocks is unquestionable, on the whole Equally unquestionable is the definite sequence of intrusions as demonstrated by the contacts of rocks of different composition Some doubt exists only as to the position of trondjemite granite and quartz diorite (see below).

Feldspathic and feldspathic quartz pegmatoid and pegmatite veins which cut the Okhotsk granodiorite and granite and which appear to be of the same age with alkalic and sub-alkalic rocks usually in the same vicinity should be considered Upper Cretaceous. Connected with these veins is a molybdenum mineralization very typical of the western part of the batholith where alkalic and sub-alkalic rocks are the most common. It is obvious that the absolute-age figures for these molybdenum veins or for K-feldspars in them will be those of the molybdenum mineralization typical of the Okhotsk-Chaun volcanic belt.

The participation in the formation of the Magadan batholith is different for rocks of different composition. It can be expressed in the following figures showing the area of their distribution (in %):

Trondjemite and trondjemite granite	less than 1
Gabbro and gabbro-diorite	2
Quartz diorite and related rocks	5
Granodiorite and adamellite	80
Granite of various compositions	10
Sub-alkalic and alkalic rocks	2

Granodiorite predominates not only among the Magadan batholith rocks but in other intrusives of the Okhotsk system and in the system as a whole.

PETROGRAPHIC AND PETROCHEMICAL FEATURES OF THE MAGADAN BATHOLITH ROCKS

Trondjemites— formations foreign to the

Table 2

The sequence of formation for the Magadan batholith

Time	Phase	Rocks	Complexes
Paleogene(?)-Late Cretaceous	II	Alkalic granite and granite porphyry Sub intrusive liparite and sub alkalic granite porphyry	
Early Cretaceous	IV	Granites of various composition	—
	III	Granodiorite and adamellite	Okhotsk
	II	Quartz diorite	
	I	Gabbro and gabbro-diorite	
Pre-Cretaceous(?)		Trondjemite granite and trondjemite	—

Magadan batholith, according to its students, were first discovered by A. M. Demin in the Ol'skiy Point outcrops on Staritskiy peninsula. Their mineral composition is as follows (in %; figures in parentheses indicated the range, after A. M. Demin):

Plagioclase	51.50(40.67–64.80)
Microcline	9.30(0–11.60)
Quartz	36.40(30.22–40.17)
Biotite	1.80(1.05–2.22)
Chlorite	0.31
Muscovite	0.24
Magnetite	0.32

The average mineral composition of the trondjemites is well illustrated by the chemical composition of specimen No. 128 from the A. M. Demin collection (see Table 3, Column 1). Their petrochemical features associate them with the Okhotsk granites; however, trondjemites are the earlier formations; in the Ol'skiy Point outcrops, they are cut by quartz diorite and by a dike of the Okhotsk granodiorite. Ye. K. Ustiyev has found a trondjemite xenolith in gabbro of Nyuklya Point. This finding, however, is unique; therefore, the trondjemite-gabbro relation remains obscure.

These trondjemites have been assigned to pre-Cretaceous, most probably Upper Jurassic formations [1]. Some northwestern geologists (L. A. Snyatkov and A. S. Simakov) believe them to be as old as Paleozoic. This last view is too speculative to be taken seriously.

Occurring along with trondjemites in the Ol'skiy Point outcrops are plagioclase and normal granite with a low biotite content; apparently, they are facies and schlieren varieties of trondjemites.

Gabbros are known from the Magadan batholith in three isolated stock-like bodies, 0.5 to 1.5 km across. They are the Bol'shaya Gabbrovaya Mountain, on Osenniy Creek; the Kamennyy Venets Mountain, on the south shore of Nagayev Bay; and Nyuklya Point, Ol'skiy Bay. In coastal outcrops at Kamennyy Venets Mountain, gabbro xenoliths are present in granodiorite, while the gabbro massif itself is cut by granodiorite veins. Present in gabbro are plagioclase, pyroxene, hornblende, and in places olivine (Nyuklya Point). The Bol'shaya Gabbrovaya rocks consist of labradorite (65%) and augite (35%) replaced by hornblende to a considerable extent. In the Kamennyy Venets gabbros, hornblende and pyroxene account for 30 to 40%, with small amounts of biotite, sphene, and titanomagnetite. Locally, the gabbros are close in composition to gabbro-diorite. Petrochemical features of the Magadan batholith gabbros correspond to those of an "intermediate" gabbro (Table 3, Column 2). Typical is the somewhat lower content of alkalies (higher content in gabbro-diorite) and iron and magnesium oxides, and a higher calcium oxide content.

The earlier formation of the gabbro is unquestionable, as shown by an analysis of the gabbro-granodiorite ratios; however, the stock-like form of gabbro bodies surrounded by granodiorite is very unusual, indeed. It appears that these gabbro stocks have been fused into granodiorite as peculiar "autochthonous xenoliths," in the interformational penetration of granodiorite magma. No contacts between gabbro and quartz diorite have been observed. A. M. Demin notes [3] the cutting of gabbro by tonalite (a phase of quartz diorite); it should be noted, however, that granodiorite veins in gabbro commonly have a hybrid aspect, similar to veins of tonalite, quartz diorite, and even gabbro-diorite. For that reason, the assigning of the cutting-vein tonalite to a diorite intrusive phase needs confirmation.

Table 3

Petrochemical features of the Magadan batholith rocks (in %)

Oxides	1	2	3	4	5	6
SiO_2	73.70	47.08	62.72	63.72	71.01	61.45
TiO_2	0.19	1.44	1.31	0.69	0.52	0.32
Al_2O_3	14.13	21.87	16.14	15.89	14.63	20.77
F_2O_3	0.50	2.28	1.58	3.20	2.31	0.76
FeO	2.21	6.03	3.16	2.76	0.97	1.23
MnO	0.04	0.04	0.05	0.11	0.06	0.04
MgO	0.44	4.73	3.02	1.86	0.71	1.31
CaO	1.93	11.81	5.23	4.65	2.14	1.66
Na_2O	3.69	2.38	3.57	3.51	2.98	3.15
K_2O	2.59	0.86	2.15	2.86	3.74	8.74
P_2O_5	0.08	0.13	0.12	0.06	—	—
H_2O	0.29	0.06	0.35	0.30	0.58	0.64
Total	99.79	98.71	99.40	99.61	99.65	100.07

Recomputed by the A. N. Zavaritskiy method

	1	2	3	4	5	6
a	11.6	7.0	11.1	11.9	11.8	19.6
c	2.3	12.5	5.3	4.8	2.5	2.0
b	5.3	20.5	10.8	9.6	6.4	8.2
s	80.8	60.0	72.8	73.7	79.3	70.2
a'	40.0	—	—	—	35.4	50.0
f'	46.2	40.9	41.4	56.4	45.8	22.5
m'	13.8	43.1	48.4	33.6	18.8	27.5
c'	—	16.0	10.2	10.0	—	—
n	68.2	80.9	71.7	65.5	54.5	35.4
t	0.2	2.2	1.5	0.8	0.5	0.4
φ	7.5	10.2	12.7	28.6	31.3	8.3
Q	36.1	—6.5	18.1	18.8	32.5	—0.8

1. Trondjemite from Ol'skiy Point [3].

2. Average of two analyses of pyroxene-hornblende gabbro from the Osenniy Creek basin in the western part of the Magadan batholith (data from the 1947 chemical analysis by S. V. Domokhotov and the 1948 analysis by K. T. Zlobin).

3. Average of two analyses of quartz diorite from Nagayeva Cove in the western part of the Magadan batholith (K. T. Zlobin, 1948; V. V. Zakandyrin, 1949).

4. Average of two analyses of granodiorite from Amakhton Bay and the Oks basin (Zakandyrin, 1949).

5. Average of four analyses of granite and plagiogranite from the Amakhton Bay coast and the Osenniy and Usinskiy deposits (V. V. Zakandyrin, 1949; L. V. Firsov and V. N. Soboleva, 1952).

6. Average of two analyses of syenite and granosyenite from the Osenniy deposit (L. V. Firsov and V. N. Soboleva, 1952).

Quartz diorites are more widely developed than the gabbros. They form bodies up to 5-10 km across and oriented in various directions. The sub-latitudinal orientation of quartz diorite in the vicinity of Magadan where it coincides with the trend of major faults defining the grabens of Nagayev and Gertner bays is very curious. Quartz diorite in the Gertner Cove carries numerous porphyrite xenoliths and is cut by granodiorite dikes.

The aspect and composition of quartz diorite ranges widely. Generally, it is a dark gray to gray, even- to medium-grained rock of a hornblende-biotite-plagioclase composition. Plagioclase content (andesine) ranges from 40 to 60%; hornblende, 10 to 30%; biotite, 5 to 10 %; quartz, up to 10%; and accessory and ore minerals, 0.5 to 2%, with sphene, zircon, epidote, apatite, and titanomagnetite the most common. The rock texture is typically dioritic.

Locally present in quartz diorite are large bodies of either granodioritic or gabbro-dioritic composition. The petrochemical features of quartz diorite (Table 3, Column 3) put it in a close relation to granodiorite.

Granodiorites are gray, uneven-grained rocks. Their average composition is (in %) andesine, andesine-oligoclase is 50 to 55; K-Na-feldspar is 5 to 7; quartz is 15 to 18; biotite and chlorite on biotite, up to 15; hornblende, 8 to 10; accessory and ore minerals, up to 1. Very characteristic is the intensive chloritization of biotite: on the average, over 60 % of the biotite has been replaced by chlorites associated with sphene and titanomagnetite. Feldspars are but slightly altered, by sericitization in plagioclase and by pelitization in K-feldspar.

The composition of the granodiorite ranges from near-tonalite to near-plagiogranite. Locally, the granodiorite looks like monzonite and trondjemite. All this makes it difficult to assign it to a definite intrusive phase; however, the number of varieties is not large and most granodiorites of the Magadan batholiths are rather monotonous rocks. Their petrochemical features (Table 3, Column 4) correspond to those of an "intermediate" granodiorite [5].

Granites of the Okhotsk complex cut the granodiorites. In outcrop, these are more or less isometric bodies, 3 to 20 km across. Their composition ranges from typically plagioclase to sub-alkalic, with the same ratio of plagioclase to K-feldspar but with the latter sometimes predominate. These are mostly medium-grained, light gray to pinkish rocks with a small amount of dark minerals. Plagioclase is represented by acid varieties, commonly albitized and appreciably sericitized. K-feldspar (microcline) is subject to albitization. The quartz content ranges from 25 to 35 %. Often present along with biotite are muscovite and alkali hornblende; the biotite is moderately to strongly chloritic. A distinctive feature of the Okhotsk granite is its high saturation in alumina, the small role of oxides of calcium and magnesium, and a depressed alkalie content observed in a number of analyses (Table 3, Column 5; Table 4)[3].

Alkalic and sub-alkalic rocks, assigned to the Upper Cretaceous-Paleogene, are poorly developed and occur only in veins of various thickness and in small stocks which cut the Okhotsk granodiorite and granite. They are characterized by coarsely crystalline granular structures, a high K-feldspar content, a moderate amount of dark minerals, a considerable muscovite content, and a wide development of sericitization and pelitization in feldspars. These rocks are marked by their supersaturation in alumina and by a certain deficiency in silica (Table 3, Column 6).

The essentially feldspathic pegmatoid and pegmatitic veins which cut the Okhotsk granodiorite and granite may be assigned, by a number of their features and especially by their molybdenum content, to the Upper Cretaceous sub-alkalic and alkalic extrusive complex. The mineral composition of these veins is dominated by microcline. The quartz content ranges from a few to 40 %; albite is present in an amount of 5 to 10 %; and there are occasional coarsely tabular and coarse blocky varieties of biotite and muscovite. Microcline usually is non-latticed or only slightly so and contains numerous perthitic and microperthitic intergrowths. A molybdenum incrustation is present both in veins and in the enclosing rocks, near quartz-feldspar veins, muscovite-feldspar greisens, and coarse aggregates of rocks with a higher alkalicity.

THE METHOD AND THE CONSTANTS

The absolute-age determinations were done by the K-Ar method, in the Magadan Scientific Research laboratory, in 1958 and 1959. From three to five identical samples were used in determining potassium oxide by the chlorplatinum method, with an average value of K_2O accepted as the true one. The amount of K^{40} (0.0122% by weight of the entire amount of K isotopes) was calculated with equation where K_2O is the potassium oxide content in weight percent;

$$K^{40} = 1,0126.\ 10^{-6} K_2O \text{ gr/gr}$$

[3]An accurate idea of relationship between the chemistry and mineral composition of rocks is best obtained from specific data for a single specimen, rather than from an average of chemical analyses by different authors. Editorial Board.

Table 4

Petrochemical features of the Magadan batholith granites (in %)

Oxides	5-a		5-b		5-c		5-d	
	Weight %	Molecular amount	Weight %	Molecular amount	Weight %	Molecular amount	Weight %	Molecular amount
SiO_2	67.48	1125	70.25	1170	72.24	1203	74.08	1235
TiO_2	0.84	10	0.41	5	0.60	8	0.23	3
Al_2O_3	15.57	153	15.36	151	14.09	138	13.50	132
Fe_2O_3	2.32	14	2.43	15	3.99	25	0.52	3
FeO	1.23	17	0.85	12	0.72	10	1.07	15
MnO	0.09	1	0.06	1	0.08	1	0.02	—
MgO	0.98	24	1.11	28	0.15	4	0.58	15
CaO	3.88	69	2.86	51	0.33	6	1.50	27
Na_2O	3.24	52	2.53	41	3.75	61	2.42	39
K_2O	2.76	29	2.64	28	3.93	42	5.64	60
P_2O_5	0.01	—	—	—	—	—	—	—
H_2O	—	—	1.32	—	0.44	—	0.55	—
Total	98.40	—	99.82	—	100.32	—	100.11	—

Recomputed by the A. N. Zavaritskiy method

	5-a	5-b	5-c	5-d
a	11.2	9.2	13.3	13.1
c	4.8	3.4	0.4	1.8
b	5.3	8.9	8.0	3.2
s	78.7	78.5	78.3	81.9
a'	7.9	46.6	47.2	25.0
f'	60.5	32.3	49.6	43.8
m'	31.6	21.1	3.2	31.2
n	64.2	59.4	59.2	39.1
t	0.9	0.4	0.7	0.2
φ	36.8	22.5	40.6	12.5
Q	30.2	35.2	29.6	35.8

5-a. Granite, biotitic, fine-grained; the Amakhton Bay coast (after V. V. Zakandyrin, 1949).

5-b. Granite, biotite-hornblendic, medium-grained; the Osenniy location (after L. V. Firsov and V. N. Soboleva, 1952).

5-c. Granite, biotitic, coarse-grained; the Amakhton Bay coast (after V. V. Zakandyrin, 1949).

5-d. Granite, leucocratic, fine-grained; the Usinsk location (after L. V. Firsov and V. N. Soboleva, 1952).

Agron was determined in samples weighing 50 and 100 gm; their fusing was done on high frequency heating installations and by heating with molybdenum coils. Argon was purified with black copper oxide, metallic calcium, a tungsten file tube, and a trap with liquid nitrogen. It was measured with Macleod gauges, with a possible error of ±1%. A practice run of the apparatus has shown that the over-all error in determining radiogenic argon does not exceed ±2%, with the over-all error in determining the Ar^{40}/K^{40} ratio not exceeding ±3%. Any effect of air argon was eliminated by a careful and prolonged application of high vacuum pumps and a proper processing of absorbents. We shall not go into details of the analytic method; those interested will find them in our earlier work [9].

The following values of the constants for K^{40} decay were used in computing the age from the Ar^{40}/K^{40} ratio:

$$\lambda_\beta = 4.68.10^{-10} \text{ year}^{-1}.$$

$$\lambda_k = 0.585.10^{-10} \text{ year}^{-1}.$$

$$\lambda_k/\lambda_\beta = 0.125.$$

The computation was done with the conventional equation for K^{40} decay, solved for time and transformed as follows, after a substitution of the constants' values:

$$t = \frac{\lg(9.00 \frac{Ar^{40}}{K^{40}} + 1)}{2.2866} . 10^{10} \text{ years.}$$

where Ar^{40} and K^{40} are in grams, per one gram of rock.

SAMPLES FOR ABSOLUTE-AGE DETERMINATION

Eleven samples were used in determining the absolute age of the Magadan batholith rocks. Their numbers are given below.

Trondjemite granite	82	Pre-Cretaceous?
Gabbro-diorite	65	Phase I
Quartz diorite	133; 134	Phase II
Granodiorite	38; 75; 0	Phase III
Granite	31; 34	Phase IV
K-feldspar from veins	24; 60	Upper Cretaceous

82. Trondjemite granite with a potassium oxide content higher than in sample used by A. M. Demin for a complete silicate analysis (see Table 3, Col. 1); Ol'skiy Point, Staritskiy Peninsula; sample 99 is from the 1956 collection of M. P. Yushinina.

65. Hornblende gabbro-diorite with biotite, banded texture; mouth of Mamaltykich River, a tributary of Yana-Okhotskaya, the Tayusk area; sample 282 is from the 1957 collection of V. V. Vesnin. This specimen is from an intrusive body adjacent to the Magadan batholith, but it is close in composition and position in other intrusive Okhotsk rocks to gabbros and gabbro-diorite of the Magadan batholith.

133. Granodioritic schlieren in quartz diorite; northern shore of Nagayev Cove; from the 1958 collection of L. V. Firsov.

134. Dioritic schlieren in quartz diorite; southwestern shore of Gertner Cove; from the 1958 L. V. Firsov collection. Quartz diorite is cut by granodiorite, plagiogranite, and aplite and pegmatite veins.

38. Granodiorite (plagiogranite); the Kamenushka headwaters, 10 km northwest of Magadan; from the 1956 collection of M. P. Yushinina.

75. Granodiorite, the most typical of the Magadan batholith; outskirts of Marchekan village, Nagayev Cove. From the 1958 collection of L. V. Firsov.

0. Granodiorite, the most typical of the Magadan batholith; stone quarry, the Magadanka-Kamenushka watershed. From the 1957 L. V. Firsov collection.

31. Leucocratic granite; upper course of Dukach River, 40 km north of Magadan; a small body of granite cutting the extrusives; specimen 93 is from the 1956 collection of M. P. Yushinina.

34. Leucocratic granite; upper course of Dukach River, 37 km north of Magadan; a granite stock cutting the Magadan batholith granodiorite; specimen 96 is from the 1956 M. P. Yushinina collection.

24. Microcline from a pegmatite vein with quartz and albite; outskirts of Marchekan village, south shore of Nagayev Cove. From the 1958 L. V. Firsov collection. A pure, slightly albitized microcline was used in the analysis. The vein cuts the Magadan batholith granodiorite and is correlative with molybdenum-bearing pegmatitic and pegmatoid veins and sub-alkalic and alkalic Upper Cretaceous rocks.

60. K-feldspar, coarsely clastic, from a vein cutting the Mamaltykich basin granite; from the 1957 V. V. Vesnin collection. The age of granite cut by the vein has been determined as 100 to 105 million years. This sample does not belong to the Magadan batholith and is cited for comparison with sample 24.

RESULTS OF THE ABSOLUTE-AGE DETERMINATIONS AND CONCLUSIONS

A total of 28 analyses have been performed; their results for K, K^{40}, and radiogenic Ar are given in Table 5.

We underscore the fair convergence of the determination results from parallel samples; also the complete convergence, within the limit of error, of course, of the age determination for rocks of a similar type, such as quartz diorite from samples 133 and 134; granodiorite from samples 75 and 0; and vein k-feldspar from samples 24 and 60.

On the whole, the geologic assumption of the age of the Magadan batholith rocks has been corroborated by the absolute-age figures. It

Table 5

Absolute age of the Magadan batholith rocks

Sample No.	Rock (mineral)	content, g/g			$\frac{Ar^{40}}{K^{40}}$	Age, million years
		K	$K^{40}\cdot10^{-6}$	$Ar^{40}\cdot10^{-8}$		
65	Gabbro-diorite	0.0195	2.38	1.975	0.00830	136
		0.0195	2.38	1.905	0.00800	132
82	Trondjemite granite	0.0286	3.49	2.78	0.00797	132
		0.0286	3.49	2.74	0.00785	130
		0.0286	3.49	2.75	0.00788	130
		0.0286	3.49	2.75	0.00788	130
133	Quartz diorite (granodioritic schlieren)	0.0260	3.17	2.38	0.00751	124
		0.0260	3.17	2.45	0.00773	127
		0.0260	3.17	2.38	0.00751	124
		0.0260	3.17	2.37	0.00748	124
134	Quartz diorite (dioritic schlieren)	0.01485	1.81	1.335	0.00738	122
		0.01485	1.81	1.38	0.00763	126
		0.01485	1.81	1.30	0.00719	119
		0.01485	1.81	1.31	0.00724	120
38	Granodiorite (plagiogranite)	0.0213	2.60	1.972	0.00759	125
		0.0213	2.60	1.940	0.00746	124
75	Granodiorite	0.0235	2.87	1.963	0.00684	113
		0.0235	2.87	1.990	0.00693	115
		0.0235	2.87	2.140	0.00745	123
0	Granodiorite	0.0232	2.83	1.965	0.00695	115
31	Granite	0.0390	4.76	3.030	0.00636	106
		0.0390	4.76	2.795	0.00587	98
34	Granite	0.0353	4.31	2.325	0.00540	90
		0.0353	4.31	2.305	0.00535	89
24	Microcline from a vein	0.0902	11.00	4.665	0.00424	71
		0.0902	11.00	5.115	0.00465	78
60	K-feldspar from a vein	0.0711	8.68	4.04	0.00465	78
		0.0711	8.68	4.02	0.00463	78

has been definitely established that the formation of the batholith took a long time, about 60 million years.

Gabbro and gabbro-diorite may belong to the earliest phase of the batholith formation. The age of gabbro-diorite in sample 65 has been determined as 136 and 132 million years, an average of 134 million years, which corresponds to the Jurassic-Cretaceous boundary. Because this gabbro-diorite does not belong to the Magadan batholith but to the adjacent intrusive body, determinations of absolute age for gabbro and gabbro-diorite directly from the Magadan batholith will be done in the future.

Contrary to expectations, the trondjemite granite turned out to be lower Cretaceous rather than pre-Cretaceous — 132, 130, 130, 130 million years old (base of Lower Cretaceous), but indeed older than quartz diorite which cut it. It is pertinent to question here the assumption according to which the trondjemite is foreign to the Magadan batholith. It is not impossible that a more detailed survey of the batholith will reveal a distribution of trondjemite and trondjemite granite wider than is known at the present time.

The age of quartz diorite, sample 133, is 124, 127, 124, and 124 million years, an average of 125 million years; sample 134 — 122, 126, 119, 120 million years, an average of 122 million years, corresponding to the middle of the Early Cretaceous and in full accordance with its geologic position. Despite the sharp petrographic differences in these rocks, their absolute age determinations coincide quite well and point to the simultaneous formation of quartz diorite in different parts of the Magadan batholith.

The age values obtained for granodiorite are rather scattered. First of all, the age of granodiorete from sample 38 turned out to be the same as for quartz diorite, i.e., 125 and 124 million years. M. P. Yushinina, who owns

this specimen, identified it as granite; a microscopic study of thin sections has sown, however, that it represents an essentially plagioclase rock, similar in structural features to granodiorite-plagiogranite schlieren bodies in quartz diorite of the Magadan batholith. This is corroborated by the low potassium content in the specimen - even lower than in the batholith granodiorite. Because of that, we are inclined to assign this specimen to dioritic intrusive phase.

The age of granodiorite in samples 75 and 0 turned out to be close, and corresponding to the middle of the Early Cretaceous, on the average of 115 million years, which is in full accordance with geologic facts: the granodiorite cuts Lower Cretaceous extrusives, but their pebbles have been found in Upper Cretaceous conglomerates.

The scattering of the age figures obtained for granite — sample 31: 106 and 98 million years, an average of 104 million years; sample 34: 90 and 89 million years, an average of 90 million years — may be due to the argon loss in granite of sample 34 which was considerable altered (sericitization of feldspars, chloritization of biotite). However, the age determination for the Tayusk granite has shown that here, too, in the basin of Yana-Okhotskaya, Mamaltykich, and other rivers, granites 100 to 105 million years old are present as well as granites younger than 100 million years and older than 110 million years. Thus a pinpointing of the age of the Okhotsk granite calls for additional study. Nevertheless, the values obtained are in full accordance with geologic assumptions and evidence, and make it possible to regard the granite as "Middle Cretaceous."

Finally, the age of K-feldspar from veins correlative with Upper Cretaceous sub-alkalic and alkalic rocks of higher molybdenum content is suggested as 75 million years, on the average, for sample 24, and 78 million years for sample 60, which correspond to the top of the Upper Cretaceous.

Thus, the history of formation of the Magadan batholith may be divided into six stages or phases, as follows:

Phase I 134 million years: minor intrusions of gabbro and gabbro-diorite, apparently preceding the flow of intermediate Lower Cretaceous lavas.

Phase II 130 million years: minor intrusions of trondjemite granite.

Phase III 122 to 125 million years: intrusions of quartz diorite, apparently contemporaneous with Lower Cretaceous intermediate lavas.

Phase IV 115 million years: a major intrusion of granodiorite magma, the main phase of the batholith formation.

Phase V 90 to 105 million years: intrusions of granite of variable composition.

Phase VI 75 to 78 million years: the formation of feldspar and feldspar-quartz veins; and apparently of small intrusions of alkalic and sub-alkalic molybdenum-bearing rocks.

At the present time, we deem it inadvisable to discuss the extent of the Okhotsk igneous complex, because that would require a large number of absolute-age determinations. However, even now the Magadan batholith fully corroborates, on the whole, the geologic speculations on some igneous processes in the Okhotsk-Chaunsk belt.

The author expresses his gratitude to G. A. Afanas'yev for a number of suggestions for this paper.

REFERENCES

1. Vas'kovskiy, A. P., A., Demin, L. A. Snyatkov, and Ye. K. Ustiyev, Domelovyye trond'yemity mysa Ol'skogo. [PRE-CRETACEOUS TRONDJEMITE OF OL'SKIY POINT]. Materialy po Geol. i Polezn. Iskop. Severo-Vost. SSSR, vyp. 3, 1948.

2. Demin, A. M., Etapy formirovaniya Magadanskogo batolita. [STAGES OF THE FORMATION OF THE MAGADAN BATHOLITH]. Ibid., vyp. 2, 1946.

3. Demin, A. M., Trond'yemitovyye granity mysa Ol'skogo i ostrova Tri Brata. [TRONDJEMITE GRANITE OF OL'SKIY POINT AND TRI BRATA ISLANDS]. Ibid., vyp. 3, 1948.

4. Demin, A. M., Morfologiya i elementy tektoniki Magadanskogo batolita. [MORPHOLOGY AND TECTONIC ELEMENTS OF THE MAGADAN BATHOLITH]. Ibid., vyp. 7, 1949.

5. Zavaritskiy, A. N., Izverzhennyye gornyye porody. [EXTRUSIVE ROCKS]. Izd. AN SSSR, 1955.

6. Ustiyev, Ye. K., Mezozoyskiy i kaynozoyskiy magmatizm Severo-Vostoka SSSR. [MESOZOIC AND CENOZOIC IGNEOUS ACTIVITY IN THE NORTHEASTERN PART OF THE USSR]. Mater. po Geol. i Polezn. Iskop. Severo-Vost. SSSR, vyp. 4, 1949.

7. Ustiyev, Ye. K., K voprosu o

monogennykh, poligennykh i geterogennykh intruziyakh. [THE PROBLEM OF HOMOGENEOUS, POLYGENOUS, AND HETEROGENOUS INTRUSIONS]. Ibid., vyp. 5, 1949.

8. Ustiyev, Ye.K. and I.M. Speranskaya, Gal'ka "okhotskikh" granitoidov v verkhnemelovykh konglomeratakh Armanskogo rayona. [PEBBLES OF THE "OKHOTSK" GRANITOIDS IN UPPER CRETACEOUS CONGLOMERATES OF THE ARMAN AREA]. Ibid., vyp. 7, 1949.

9. Firsov, L.V., Konstruktsiya argonovykh ustanovok i metodika opredeleniya absolyutnogo vozrasta po otnosheniyu Ar^{40} k K^{40} v laboratorii Magadanskogo instituta. [DESIGN OF ARGON INSTALLATIONS AND METHODS FOR ABSOLUTE-AGE DETERMINATION BY THE Ar^{40}/K^{40} RATIO IN THE LABORATORY OF THE MAGADAN INSTITUTE]. Ref. sb. za 1958 BNII-1, Magadan, 1959.

The Magadan Scientific Research Institute for Gold and Rare Metals (All-Union Scientific Research Inst. - 1)

Received, June 7, 1959.

CLIMATIC DATA DETERMINING THE LOWER STRATIGRAPHIC BOUNDARY OF THE PLIOCENE [1]

by

A. I. Moskvitin

Assuming climate to be the main factor determining the distribution of flora and fauna, geologists have long applied climatology to historical geology; they have created a new discipline of paleoclimatology and have made it a tool of stratigraphy. Stratigraphic subdivisions obtained through paleoclimatology have been especially important for the period closest to us, the Quaternary, where a comparison with the present, is fully applicable. Evidence of the general cooling of the earth's climate has been traced, along with that of strong periodic changes, from a climate similar to the present, during interglacial periods, to the arctic and temperate latitudes, during glaciations.

For most Quaternary geologists, such achievements of climatology have become textbook truths. There are, however, some obscure points in the description of the climate of ancient glaciations (glaciations assumed to be Pliocene but localized in mountain regions or else believed to represent unusually warm periods and incapable of changing the climate of entire continents) which bring us back to the question as to where the Pliocene-Pleistocene boundary really is.

Even prior to the Nineteenth Session of the International Geological Congress, data accumulated on the changes of the Late Pliocene climate of Europe, judging from the changes in flora and fauna, forced geologists to include within the Pleistocene a number of ancient deposits supposed to be Pliocene. Such were the red and forested shell beds of the east coast of England; Tegelen and pre-Tegelen; Itzen (Itzehoe) and Amstel deposits of Holland and northwestern Germany; and Villafranchian and Calabrian deposits of southern France and northern Italy. The Congress accepted the appropriate recommendations for a change in appropriate recommendations for a change in the Pliocene-Pleistocene boundary.

The main climatologic basis for pushing the Pleistocene base back into the Pliocene is as follows. The alleged Pliocene sediments of the North and even the Mediterranean seas were found to carry a boreal to arctic fauna of fora-minifera and mollusks; walruses appeared off the Netherland coast, as witness the occurrence of their bones with the remains of the last mastodons and primitive elephants; the southern type forests of Italy gave place to the deciduous, and to exclusively coniferous forests during glaciations, with complete disappearance of typical Tertiary forms (Liquidambar and Sequoia) long before the end of allegedly Tertiary sedimentation (Villagranchian); evidence of a marine regression related to the concentration of water in glacial mantles was found in sediments of the west and south coast of the North Sea; finally, cryoturbations, evidence of permafrost, were found in the same "Pliocene" deposits along the lower Rhine, in an area seldom frozen up at the present time.

Similar change in the flora (pollen) and lithologic evidence of a glacial climate were noted by this author and other students of the Pliocene of eastern Europe. I commented on all of these facts in several papers, of necessity to a different extent. While the data necessary to form a correct judgment on the changes in flora and fauna were summarized in fair detail, with lists, tables, cross-sections, maps, and pollen diagrams, more definite and the more objective evidence of ancient glaciation, most strikingly expressed in cryoturbations of the Netherlands, was recited in someone else's language (from observations of F. Florschutz and A. van Sommeren). On the other hand, the corresponding observations from the U.S.S.R. were not convincing for some members of our special Quaternary Commission of 1957. G.I. Goretskiy [2] voiced the opinion that these cryoturbations might be evidence of slides. Moreover, there had been a lack of palynologic evidence in Holland, where it appeared only in recent years; in our country, the main reasons for lowering the base of the Pleistocene were not yet published. That gap has been filled with the publication of my papers on the Middle Volga [12] region and the Yergeni sequence [13]. In addition, new evidence, not yet published, has been obtained in excellent

[1] Klimaticheskiye dannyye, opredelyayushchiye nizhnyuyu stratigraficheskuyu granitsu Pleystotsena.

cryoturbations from the Yergeni sands.

The comments after the presentation of my reports and during the inspection of these newly-discovered cryoturbations[2] have brought to light another very important obstacle preventing a number of quaternary geologists from grasping the value and the irrefutable quality of the mute criteria of permafrost in sediments. Perhaps, because of the brevity of exposition of these phenomena in published papers on permafrost and the lack of appropriate texts, there is a definite lack of understanding and deficiency in observing and deciphering the traces of permafrost. We shall return to this topic, illustrating it with appropriate examples.

Obviously, there is no need to rehearse here my recent review [9, 10, 11, 12] of data on the change in flora and fauna in the U. S. S. R., England, France, and Italy, at the onset of ancient, as early as "Pliocene", glaciations; however, it is expedient to pause for new palynologic and paleocryologic observations in the U. S. S. R. and along the lower Rhine. G. I. Goretskiy ([2], p. 40) states in his disbelief of permafrost phenomena which I described from the top of the Kinel' beds: "The traces of kneading by pack ice are common deformations in Kinel' clays, originating in differential compaction and in slide phenomena along the Kinel River banks (with slopes up to 10 or 20°). They have nothing to do with glacial warping." The fact is, however, that I have described off-shore lacustrine, or more exactly marine Akchagyl deposits; they carry a marine Akchagyl fauna in near-by coves at Mordovo and Bektyashka villages (A. S. Kes' [4]; Ye. V. Shantser, oral communication). The exposure is located in the middle of a bay, away from shores which could have been the place of origin of their sliding. In addition, the position and size of the warped exposure (a very limited one) are different from those of a slide: the warping is present not in oozes but in sand and in pebble beds. In another example, at Bektyashka pier, the warping is reflected in the contact zone between sand and overlying ooze; here, too, an explanation by slides is quite impossible because of the localization of the phenomena which has a very characteristic aspect ([12], p. 27). They are very similar to marsh frost disturbances which I observed in most recent extra-glacial deposits near Lagoysk, Belorussia ([8], p. 157) and at Vladimirovka village, the Syzran Trans-Volga Region ([12], p. 179).

The last sentence of the G. I. Goretskiy quotation will have to be interpreted as an unfelicitous expression of the view on permafrost warping under the conditions of a periglacial climate, because I have never mentioned any "glacial warpings."

---

[2]Frost warpings were discovered during a well-attended field trip.

Early in 1957 appeared ([11], p. 9) my description and a scale photograph of frost cauldrons at the mouth of Belaya River, at Barsukovo village. Younger examples of similar phenomena were described by A. I. Pryakhin [19]. It is quite unreasonable to take them for slides, as G. I. Goretskiy insisted on doing in our 1957 Quaternary Conference. Warped to form a cauldron are sands of a single bed, less than 1 m thick, resting among quite undisturbed horizontally stratified, fairly coarse sands, deposited, judging from the steep cross-bedding in upper beds, in the littoral-beach zone of a temporarily regressive Akchagyl sea. Deposited in deeper waters of the same basin were the "terracotta" clays underlying and overlying the beach sands ([11], p. 8). No traces of slides were found in clays and sands during the inspection of that exposure by a large group of geologists of Moscow State University, in the fall of 1956. For this reason, the G. I. Goretskiy assumption of slides should be categorically rejected and another explanation should be sought.

Cauldrons in the warped bed at Barsukovo village are isometrically round, of which we have made sure by digging across one of them ([11], p. 9, Figure 3). They are wide for their depth, in which lies their difference from the standard: they are only 0.75 m deep and 1.5 to 1.6 m wide.

Cauldron-like structures originate in an active bed (i. e., thawing out in the summer) above frozen ground, as one of the varieties of "tundra spots." The bottom of such a cauldron naturally cannot be located in the permafrost; consequently, the thickness of an active layer can be judged from the depth of the cauldrons. The shallow depth of the Barsukovo cauldrons suggests rather rigorous conditions, with the summer thaw not penetrating below 0.75 m, even in open coastal sands.

The most indicative among other traces of permafrost are "ice wedges," which are soil replacements of ground ice. These ice wedges are developed under most rigorous polar conditions, where the ground surface hardly thaws out even in the summer. Evidence of such ice wedges has been observed in the Volga and the Caspian regions, below the Akhtuba bed of the beginning and the middle of the Kalinin glaciation with its rigoroud continental climate.

Growing out of their original frost-induced fractures, ice wedges exercise a strong pressure on their walls. As a result, the enclosing beds are gathered into small folds dying away laterally; more commonly, however, they only are bent upward at the edge walls, with coupled rollers formed above the edge—the "ears"—consisting of displaced lateral material in a volume proportionate to the size of a wedge (usually up to 0.5 m high).

The ground pseudomorphs of ice wedges is the best and most incontrovertible evidence of bygone permafrost or of climate of an ancient extra-glacial region. Their aspect is well

known and they do not require additional explanations, save perhaps for subsequent distortions acquired in an active layer, under somewhat milder climatic conditions. An incipient solifluction[3] and various ground movements in an active layer, the cryoturbations, bring about deformation in the pseudomorphs, distortions, and even cutting off the upper part from the lower which remains in the frozen ground. The wedges are commonly bottle-shaped, narrowing toward the top, probably due primarily to a collapse of the "ears" into a hollow left by the ice; the wedges commonly are completely closed. Their angular forms become rounded, as if fused; the outlines become curly. Quite often the enlarged part of a wedge is changed to a cauldron with a typical concentric structure of the ground. The top of the wedge is found below the cauldron or even to the side of it (Figure 1).

The frost effect is perhaps most common in "involutions" and all sort of "cryoturbations" appearing in an active layer in connection with the development of soil structures, solifluction movements, and micro-shifts in freezing previously thawed spots. The visible shifts are usually downward, though at a very gentle slope; and even without an appreciable slope, in the last example. A fine plication is brought about when a bed, usually of slimy sand 0.3 to 0.5 m thick, is gathered into a sinusoid over a distance of 10 to 15 m.[4]

Originating along with such simple forms are more complicated ones, including those showing bizarre loops of slimy to clean beach or perhaps floodplain sands. Warped up layers may alternate vertically several times with undisturbed ones, apparently reflecting a sedimentation to the same depth as the summer thaw.

Such cryoturbations are satisfactorily explained (according to A. Bahr, [26]) by stresses originating in a water-saturated sand bed, frozen on the top and underlain by permafrost. Some spots freeze faster and form "pressure centers." The thickness of a warped layer should be proportionate to the depth of summer tahw, but somewhat shallower. It usually does not exceed 1 m, attaining sometimes 2 to 2.5 m, as in exposures which I observed at Barnaul on the Ob [15] and at Lipino village, the Lenin district of Kurskaya Oblast' [7]. Those deformations cannot be explained by soil creep.

Such cryoturbations are very common in upper alluvial exposures above floodplain terraces on the Volga (especially the IV above the floodplain terrace), deposited under periglacial conditions of Middle and Upper Pleistocene glaciations [12, 13].

Recently, as mentioned before, they have been observed also in such ancient deposits as the Akchagyl and Yergeni, thereby confirming my assumption of Akchagyl time being contemporaneous with first glaciation in the Russian plain [11].

For lack of space, detailed descriptions will have to be replaced by an abgreviated outline of two interesting exposures inspected on a well-attended field trip by Quaternary geologists, at the end of the summer of 1958. The two exposures are, on the whole, similar. One is located 7 km west of the outskirts of Rostov-on-the-Don, at Leventsovka village; the other 120 km east of there, in the lower course of Sal River, 6 to 7 km above Nesmiyanovo (Grom-gora). At both localities, the Yergeni sands (the "Khaprov," near Rostov) are exposed in quarries; the exposures are clean and fresh, with the sands lying below a sequence of closely associated brown-red "Scythian" clays (eroded down 1 to 2 m above the base, at Rostov) and into two series by traces of erosion.

The upper series consists of light-colored, mostly cross-to diagonally-bedded quartz sand; the lower one consists of similar sands locally kneaded in an active permafrost layer. An alternation of disturbed and undisturbed sands has been observed in the Leventsovka quarry (Figure 2). Because of the observation conditions (hard rain) the warping effect in the Grom Mountain quarry was sketched only by myself (Figure 3); in the Leventsovka quarry it was observed and photographed by all participants (Figures 2, 4). However, similar warping phenomena in similar sands were photographed 5 km east of Grom-gora at Rubashkin hamlet, by Yu. M. Vasil'yev, in 1957 (Figure 5). Along the erosion line, only a layer of ferruginous quartz with coarse quartz gravel has been observed in the Grom Mountain quarry, while there is local accumulation of gravel, pebbles, and clay balls in the Lenentsovka quarry where they form a true basal unit. Present in the latter are numerous bones and teeth of Elephas planifrans Falc., less commonly of Equus stenonis Koch., and occasional Struthio ostrich bones (of a different degree of preservation, more intensively fossilized).[5] The lower series is

[3]Jan Dylik, who is developing a detailed theory of past frost phenomena, describes as "congelifluction" a frost-induced ground creep, believing that solifluction is a more general congelifluction phenomenon, prevailing in lower latitudes. I regard the term, congelifluction, superflous because, under our conditions, no other soil creep except that induced by frost and by repeated thawing and freezing of an active layer, has been observed, for all practical purposes.

[4]Only 56 cm in the example cited from the Netherlands by L. Straaten, below.

[5]V. Yan'kova, a scientist at the Regional Museum of Entomology wrote in the Rostov newspaper "Molot", January 18, 1959 (in an article, "Interesting Findings") of ostrich bones newly arrived at the Museum from the Leventsovka quarry. Earlier findings were of bones of "of a mastodon, a large southern elephant, a rhinoceros, and a saber-tooth tiger and other predatory animals."

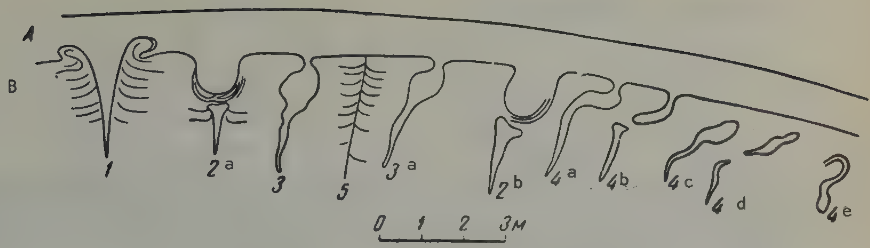

FIGURE 1. Diagrammatic view of various ice-wedge pseudomorphs (vertical section).

1) a symmetric wedge with "ears" (Odintsovo, Ochakovo villages); 2a) wedge transformed into a cauldron, in situ (Verkhniye Kotly village); 2b) same, with the cauldron displaced down the slope (Sumor'yevo, Avdeyevo village); 3) wedge half-closed by sliding "ears"; 3a) similar wedge slightly displaced by solifluction; 4a-d) wedges distroted and broken up by solifluction (Stalingrad, the Osadnaya Ravine); 4e) "ear-ring" or "tear drop" from similar and other, as yet unexplained, formations; 5) trace of a thawed wedge, with the hollow closed for lack of a filler; layers of lateral rock are bent; the bending is shown only for wedge 1.
A - upper layer, usually the filler; B - lower layer enclosing the pseudomorphs.

FIGURE 2. The Leventsovka sand pit near Rostov-on-the-Don. Example 2 of cryoturbations: two layers of warped sand separated by undisturbed sands. The base of an upper sequence with clay concretions and bones of Elephas plainfrons Falc is seen on top.

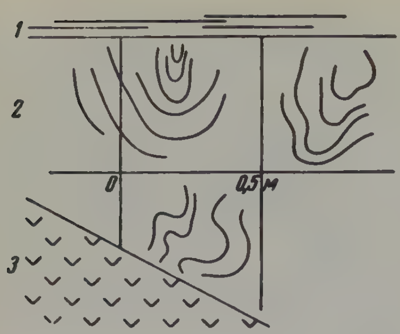

FIGURE 3. A scaled diagram of twisted sand in the lower sequence from Grom Mountain on Sal River, near Nesmiyanovo village.
1) ferruginous coarse sand at the base of the upper series;
2) frost-twisted sands;
3) talus.

only 3 to 4 m thick in its segments of twisted sand beds at Leventsovka. It is underlain by about 2 m of yellow-gray slaty limestone (Meotis) and by gray Sarmatian clay. Below the water's edge at Nesmiyanov hamlet, the Yergeni sand rests directly on clay. The warping has been observed in three places in the Leventsovka quarry, 75 to 100 m apart. In the middle locality, these sands rest upon gently, diagonally cross-bedded sand, below which there is the second unit of warped sand beds. These sands are 1 to 1.2 m thick, with the intervening cross-bedded sands 0.5 to 0.75 m thick. Locally the top of the lower cryoturbation sands changes to lenticular gray oozes with a coarse lenticular stratification. All attempts by the pollen laboratory at the Geological Institute, the U.S.S.R. Academy of Sciences (L. L. Skiba) to obtain some pollen from these oozes as well as from clay intercalations in the overlying sand and the Scythian clay, were unsuccessful. Pollen is seldom preserved in continental deposits of the south; perhaps it never got into these particular deposits, if they were deposited under glacial conditions. The cryoturbation evidence of glaciation here remains unsubstantiated, although it is not the only one, as shown in my paper on the Yergeni sequence [13].

It appears that a complete understanding of climatic changes in the Akchagylian and Apsheronian will be gained only after the publication of I.P. Maslova's study (Oil and Gas Scientific Research Institute) of cores from boreholes in the Cis-Caucasian foredeep.

Along the Middle Volga, as shown by A.V. Vostryakov et al [1] and in my own monograph and papers [10, 11, 12], evidence of permafrost in Akchagyl deposits is generally combined with the presence of a pollen assemblage of dark coniferous tayga (virgin forest), although even there pollen is missing in the warped beds themselves, probably primarily because of the lack of vegetation. There are numerous typically lenticular deposits, and occasional traces of kekyphi and of transportation of chunks and boulders by ice floes.

In the Kama region, G.I. Goretskiy [2] has determined a number of climatic changes, by pollen from the Kinel'-Akchagyl-Domashkino beds. There were warm and cold cycles, with the latter, in his opinion, never attaining the status of glaciations. However, it is easily demonstrated, as has been done in my special paper, that this view is at variance even with G.I. Goretskiy's data. It can be inferred from his diagrams ([2], Figure 3) that only dark coniferous tayga yielding the pollen of spruce, pine, and fir, persisted along the lower Kama and elsewhere, toward the beginning of the Akhchagyl sea trangression.

Incidentally G.I. Goretskiy himself sees evidence of the advent of a cold time of the "true" continental "Mindel" glaciation, in the appearance of the pollen of such "cold-loving plants" as Betula nana L. and Selaginella selaginoides Link among the pollen and spores of the same dark coniferous tayga, even "with isolated representatives of broadleaf forms, linden, elm, and oak." It is this very pollen of dwarf birch and the spores of a polar Selaginella that have been observed in a tayga horizon of the Kinsel sequence, in which I perceive traces of frost and the first glaciation. It is reasonable to ask therefore, that since not a trace of leafy trees (let alone the broadleaf ones) is left in the Kinel-Akchagyl tayga assemblage, why is that glaciation different from a "true" one?

These facts make the views of G.I. Goretskiy [2] on the advisability of leaving the "lower boundary of the Quaternary as is" (not equating the "Russianized Mindel" of the Oka glaciation and the Akchagyl) at variance with the true situation and with the scope of our knowledge. The first glaciation, which occurred in the Akchagyl, was not during a warm time, of course; nor was it exclusively a mountain glaciation but rather continental in extent, with the deposition of moraines and other glacial features in the glacial region, and with permafrost extended over a broad periglacial zone embracing all of eastern Europe. In the north, in the Kama region (Barsukovo), the ground thawed out but little in the summer; in the south, near Rostov, it thawed out somewhat deeper.

Let us now look over the contemporaneous situation in Europe with its mild marine climate. As I have noted [9, 11], F. Lona and S.

FIGURE 4. The Leventsovka sand pit near Rostov-on-the-Don. Example 1 of cryoturbations with a detail of warped bedding becoming undisturbed, on the left. Hammer is stuck at the base of an upper sand series which truncates the lower one.

Venzo demonstrate that as early as the oldest phase of the Dun_{II} Danubian glaciation assigned to the Villafranchian Pliocene, Alpine vegetation descended from 1200 or 1800 m above sea level down to at least 400 m, where its remains are now found. Considering the very probable recent uplift of that region, I believe that the former lowering of vegetation belts, and consequently of the snow line in the Southern Alps, was even greater. Generally speaking, it is quite commensurable with the lowering of the snow line during the Middle and Upper Pleistocene Alpine glaciations. And even if no glacial deposits of the "Danubian phases" of most ancient glaciations have been found in the Alpine foothills, as yet, they are known from the Caucasus as the lower of the two El'khotovo moraines described by M.S. Shvetsov[6] (1928) from the thick "Akchagyl-Apsheronian" series of continental deposits. A contemporaneous plains-land glacial moraine was discovered by drilling in the valley of the "ancestral Kama" near Solikamsk.

Just as strong evidence of permafrost was uncovered in pre-Tegelen deposits of the Netherlands and the Rhine border region of Germany. New data on it, confirming the observations of F. Florschütz [29] and A. van Sommeren [1948] briefly mentioned above, appeared recently in the Dutch and German geologic literature. As early as 1951 a paper of R. Wolters was

[6]Discovered by V.G. Orlovskiy in 1926; observed later also by A.L. Reingard [20, 21] and V.P. Rengarten [22].

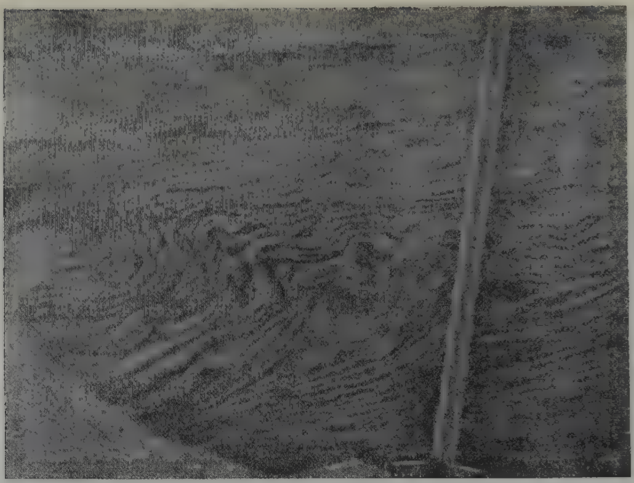

FIGURE 5. Frost-induced plication in the Yergeni sand near Rubashkino hamlet, on Sal River. Photo by Yu. M. Vasil'yev, 1957.

published, describing and illustrating pseudomorphs of ice wedges in the Reuverian Pliocene clays and filled with the oldest Quaternary gravel sand - älteste Diluvialschotter[7] (Figure 6).

The pseudomorphs are up to 2 m deep and 15 cm wide. As seen in the sketch, they are twisted and torn apart after having been formed by permafrost movements; in this sense, they are fully comparable with those examples which I have observed (compare Figure 6 and Figure 1). They appear here below the oldest "Schotter," along with other evidence of a higher activity of river ice. As early as 1910, G. Fliegel [43] found quartzite boulders up to 70 cm long, in the basal rubble; for that reason, he believed these gravel-rubble sands to be glacial. R. Wolters, too, found quite rough quartz and quartzite boulders as large as a head and, what is more significant, chunks of soft rocks, such as phyllite, whose transportation by water must be ruled out. Overlying these sands is quite undistrubed Tegelen clay with remains of a warm interglacial climate, including Carya, Pterocarya, and Tsuga. R. Wolters believes the permafrost evidence is from the Günz glaciation; however, in his paper read before the German Geological Society (abstract published in the following year, [45], he suggested the Danubian glaciation as the more probable; he was careful not to correlate such distant provinces as the Netherlands and Northern Italy (the Leffe Series).

Pollen analyses for that border province (Brüggen-Wenlo) were made by Miss Muckenhausen and V. Brelie, with a summary published by U. Rein [37]. The following pollen is typical of the Reuverian Pliocene clays: of the Pinus haploxylon type, 0 to 10%, together with Pinus silvestris; Tsuga, 0 to 8%; Scyadopitys, 2 to 8%; Sequoia and Taxodiodites hyatus R. Rot., Juglans, Carya, and Pterocarya, 0 to 20%; Fagus, 1 to 10%; Castaneoidites exactus R. Pot., Liquidambar, and types of Nyssa aquatoid.

Typical of the Tegelen clays, Tsuga (0 to 2%); Cupressinae, Juglans, Carya, and Pterocarya (0 to 15%) are still present, but Pinus of the Haploxylon type, as well as Sciadopitys, Sequoia, Taxodiodites, and Nyssa are totally missing. The Tegelen clay flora should be regarded as belonging to the first interglacial period.

In drilling in the Meinweg-Herkenbosh area, the Netherlands, somewhat later, clay sediments with pollen were found on the stratigraphic level of pre-Tegel sands; they corroborate the existence of a glacial climate. Their pollen diagram has been published by W. Zagwijn ([48]; see Figure 7). Its lower part embraces the Reuverian Pliocene clays, with the middle part, the glacial one, corresponding to the "sub-Arctic park landscape" of the first, the pre-Tegel, glaciation. As mentioned by W. Zagwijn ([48], p. 239), pollen data on the contemporaneous marine Amstel beds were obtained by J. W. Doppert and J. Zonneveld [28] from the Hertogen borehole, and from a Zeeuws-Vlaandern borehole by W. Zagwijn himself. On the basis of their mollusk fauna, beds corresponding in pollen content to the first half of pre-Telegen actually belong to Amstel littoral section, in their lower part; and to the Itzen, in the upper.

The top of the overlying interglacial Tegelen

[7]The clay pit, described by R. Wolters, is located in the Dierhart Forest, near village Hubertus Quelle.

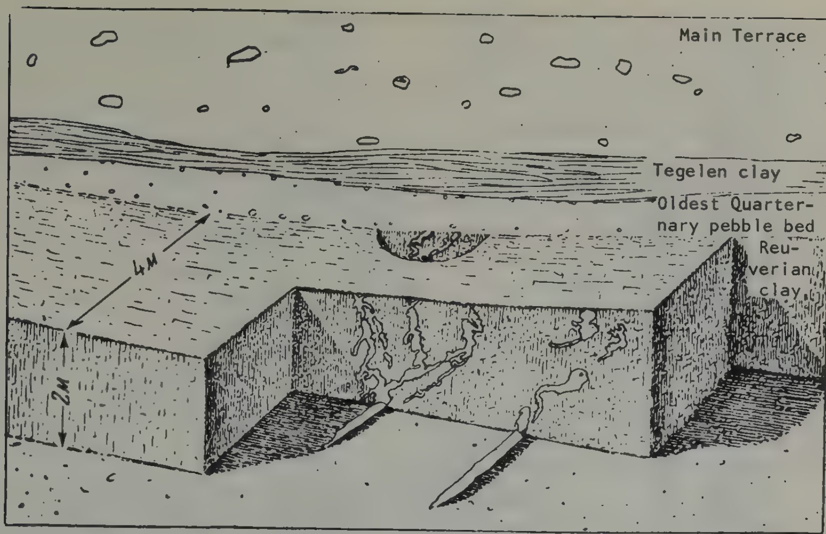

FIGURE 6. Block diagram of the Reuverian clays trim, with twisted pseudomorphs of ice wedges in the Hubertus Quelle quarry, lower Rhine. Generalized sketch by R. Wolters.

clays[8] was found to carry evidence of permafrost, similar to that present in the top of the Reuverian clays. This evidence is more plentiful in the overlying "papzand,"[9] the "Kedihem series" sands, with traces of ice wedges found in the middle of it (Figure 8) and a buried soil with the pollen of broadleaf trees (up to 10%) in the upper. Van Straaten [38] describes numerous examples of frost phenomena. They all took place prior to the Kromer interglacial time, with nut trees and tsuga flourishing in the "Vaal" warming up period (Carya, Pterocarya, Tsuga); they finally died out during the following glaciation, named Menapian (Figure 9) by W. Zagwijn [48]. The two Kedihem series Kedihem series glaciations, the Elburonian and the Menapian, are correlated by W. Zagwijn with Stages I and III of the Alpine Günz, according to F. Lona and S. Venzo [33, 49]; see Figures 10 and 11.

The W. Zagwijn paper [48] gives a stratigraphic differentiation of the Lower Pleistocene of the Netherlands and correlates it with other countries. Also participating in the working out of that section, which turned out to be fairly complicated, were G. Sluijs [32], J. Zonneveld [49]. F. Florschütz [29], and a number of other authors. A survey of the Stratigraphy of lower Rhine terraces is given in papers of H. W. Quitzow [36] and J. Zonnenveld [50], included in the two symposia on the Netherland Pleistocene, in issues 18 and 19 of the Holland Mining-Geological Society (Geologie en Mijnbouw, No. 12, for 1956; and No. 7 for 1957) which contain much interesting and valuable material on pollen, geomorphology, stratigraphy, and neotectonics. It is beyond the scope of this paper.

The equivalence in duration and climate, which I noted ([10], p. 11) between the Danubian and Günz, and Middle and Upper Pleistocene interglacial periods, enabled W. Zagwijn to group the glacial and interglacial periods in a manner somewhat different from the way it is done in works of S. Venzo and F. Lona for the South Alps. According to W. Zagwijn, there are three climatic phases in the Leffe series (North Italy) correlative with the Netherlandian: Danubian I, Günz I, and Günz II, corresponding to glaciations (pre-Tegelen, Eburonian, and the Menapian, respectively), while Stages Danube III and Günz II should be regarded merely as temporary coolings within the corresponding interglaciations (Tegelen and Vaal; see Table on p. 41).

W. Zagwijn believes that such a representation demonstrates a remarkable similarity in Lower Pleistocene stratigraphy of North Italy and the Netherlands. The Günz-Mindel interglacial period, corresponding to the Kromer, is the first one without tsuga and nut trees (Carya-Pterocarya-Tsuga).

W. Zagwijn assigns the Günz-Mindel to the Middle Pleistocene. It comes out that way in my classifications, as well [10, 11]; however, the U.S.S.R. Pleistocene begins with the Likhvinsk interglacial period which is supposed to be a younger one, the "Mindel-Riss." To be sure, as noted by W. Zagwijn himself, after V.

[8]Tegula-Latin for tile; tile clays have been worked since Roman times; one of the villages in this district has the Hollandized name of Tiglia.

[9]Papzand-oatmeal sand, a local name applied to other sands, as well.

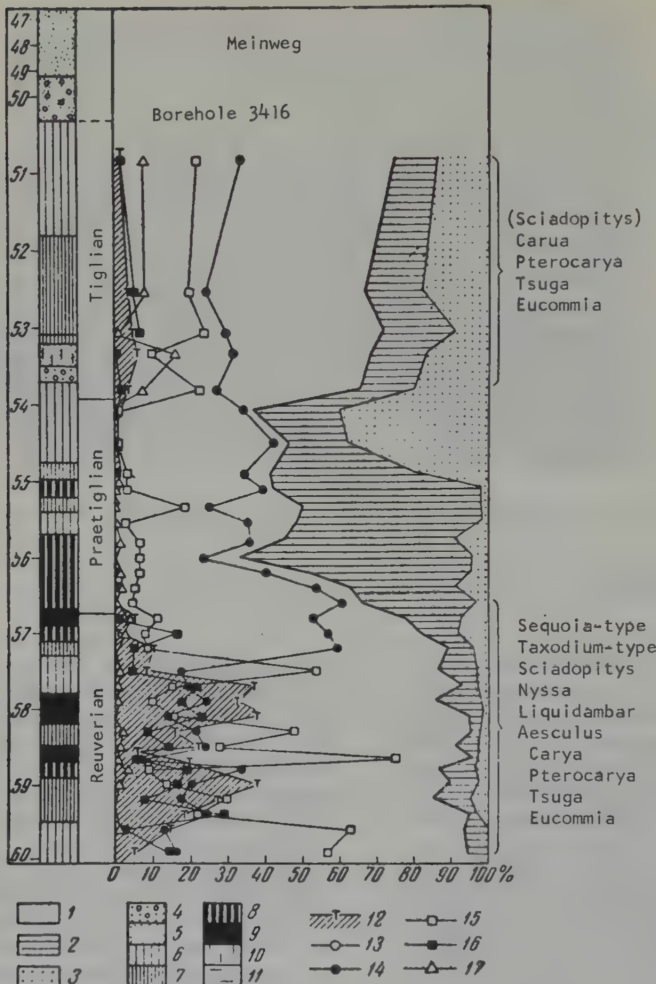

FIGURE 7. Pollen diagram from data obtained from the Meinweg-Herkenbosh borehole, the Netherlands. After W. Zagwijn.

1) tree pollen; 2) wind-pollenized grasses; 3) heath brush; 4) coarse sand and gravel; 5) fine sand; 6) clay; 7) humus clay; 8) clay, very rich in humus (clayey brown coal); 9) brown coal; 10) clay present; 11) humus present; 12) total pollen of Tertiary trees (Sequoia, etc., Carya, etc.); 13) Betula; 14) Pinus; 15) Alnus; 16) Quercetum mixtum; 17) Picea.

Vialli [41], the Günz-Mindel interglacial period is still marked by the presence of Archidiscondon meridionalis Nesti, in the Leffe series. Remains of that elephant occur in a forest horizon assigned to the Günz-Mindel-Kromer, by W. Zagwijn (see table on p. 41), as well, but they have not been observed in the Likhvinsk interglacial beds for which Elephas trogontherii Pohl, is regarded as typical, in the Soviet Union. These discrepancies may be eliminated by future findings. It must not be ruled out, however, that the Kromer interglacial period will have to be placed somewhere deeper, if not in the Tegelen, as I did [10], or in the Danubian-Günz interglaciation (which turned out to be impossible on the basis of Dutch pollen, according to W. Zagwijn), then perhaps in the "Vaal," a new interglacial period

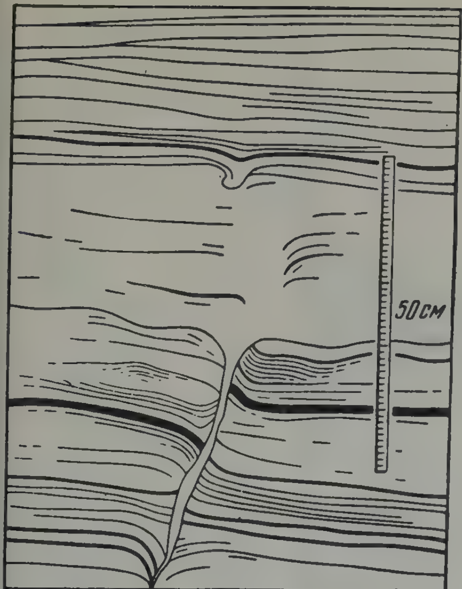

FIGURE 8. Trace of an ice vein in the Papzand sand, the Kedihem series; after Van Straaten [38].

period within the Günz. The correlation of Dutch and British glaciations is evidently not clear to W. Zagwijn himself; he has left an empty space for English "Eslter" above the Kromer interglaciation.

In any event, it is clear from an analysis of data on the Lower Pleistocene of the Netherlands that there was more than one interglacial period (Danubian-Günz-Kromer, or the "Sandomir" of my classifications; [9, 10]). There were at least two if not three and perhaps four (Tegelen, Vaal, and Kromer, of the W. Zagwijn classification).

It should be noted, in this connection, that if the "Kromer" of the new Dutch classification is indeed correlative with the "Likhvin," there can be no objections raised to my correlation of the Dnieper glaciation with Mindel I; the Moscow, with Mindel II; and the Riss with the Kalanin. These correlations may need more proof, but the necessity of assigning to the Pleistocene a considerable portion of the Pliocene, characterized by standard glacial and interglacial periods is unquestionable.

W. Zagwijn also studied ([48], p. 243) pollen from the entire thickness of the Reuverian Pliocene in the Netherlands and classified its phases of cooling; however, their effect on vegetation was "incomparably weaker." For that reason, he believes that the Pleistocene should begin from the Reuverian and pre-Tegelen deposits.

It is possible that deposits noted by G.I. Goretskiy [2] in the Kinel clay belong to these Pliocene climatic changes. However, the situation is not quite clear and requires a more penetrating paleobotanic and stratigraphic study.

Another province where valuable data on the lower boundary of the Pleistocene have been obtained by M.M. Tsapenko and N.A. Makhnach, with more data undoubtedly forthcoming, is Belorussia and particularly some areas of the Poles'ye which have a tendency to subside and accumulate sediments. The Pliocene and Lower Pleistocene of the Voronezh-Tambov trough, the very place where P.A. Nikitin and M.N. Grishchenko later started to study the continental Pliocene of this country also is inadequately known. Thick sequences in that plains-land province lie below the river water level; they have been uncovered almost exclusively by drilling.

Very fruitful for the drawing of the lower Pleistocene boundary has been the work of I. P. Maslova (Oil and Gas Scientific Research Institute) in the Cis-Caucasian foredeep, accompanied by palynologic study of deep cores. The results of this work, now in progress, promise to ve bery interesting.

No less thick are Quaternary deposits in the upper course of the Ob. However, many floral assemblages, the indexes for interglacial periods, are missing in Siberia, making the flora monotonous and inarticulate. Lower Pleistocene aeolian clays occur deep below the river water level and are little known. It is possible

	Alps (after S. Venzo)	Netherlands (after W. Zagwijn)
Interglacial period	Günz/Mindel	Kromer
Glaciation	Günz III	Menapian
	Günz II/III	
Interglacial period	Günz II	Vaal
	Günz I/II	
Glaciation	Günz I	Eburonian
Interglacial period (with an onset of cold - Danubian III)	Danubian/Günz Danubian III Danubian II/III	Tegelen
Glaciation	Danubian II	pre-Tegelen

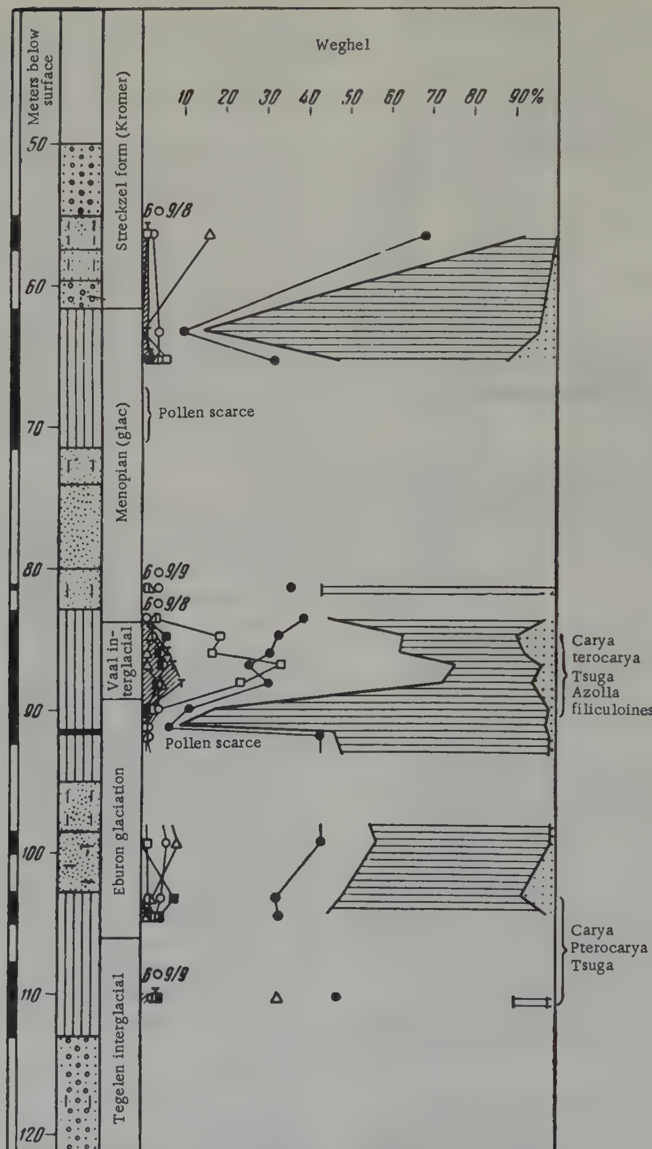

FIGURE 9. Pollen diagram from the Weghel borehole. After W. Zagwijn [48]. Symbols the same as in Figure 7.

that complete parallelism of Early Pleistocene events will be established for western and eastern Europe[10] as a result of future special study in this field. However, even now there are no reasons to assign these events to the Pliocene, as is done by G.I. Goretskiy, overawed by the "antiquity" of the Akchagyl; nor is there any reason to estimate the duration of the Quaternary, in its new interpretations (including the Apsheronian and Akchagyl), at 3.5 to 4 million years, according to V.I. Gromov, I.I. Krasnov, and K.V. Gromov ([3], p. 7). As shown by the study of deep oceanic oozes by J. Og (from Urri's computations), C.D. Ovey [34], and G. Arrhenius [25], the entire period of time marked by recurring glaciations comprises 1 to 1.5 million years. The coincidence of (sea-bottom) ooze core sections with cold and warm effects as

[10]Netherlands and North Italy, Poles'ye, Don-Voronezh trough, and Kinel-Akchagyl and perhaps Apsheronian deposits of the Volga and Cis-Caucasus regions.

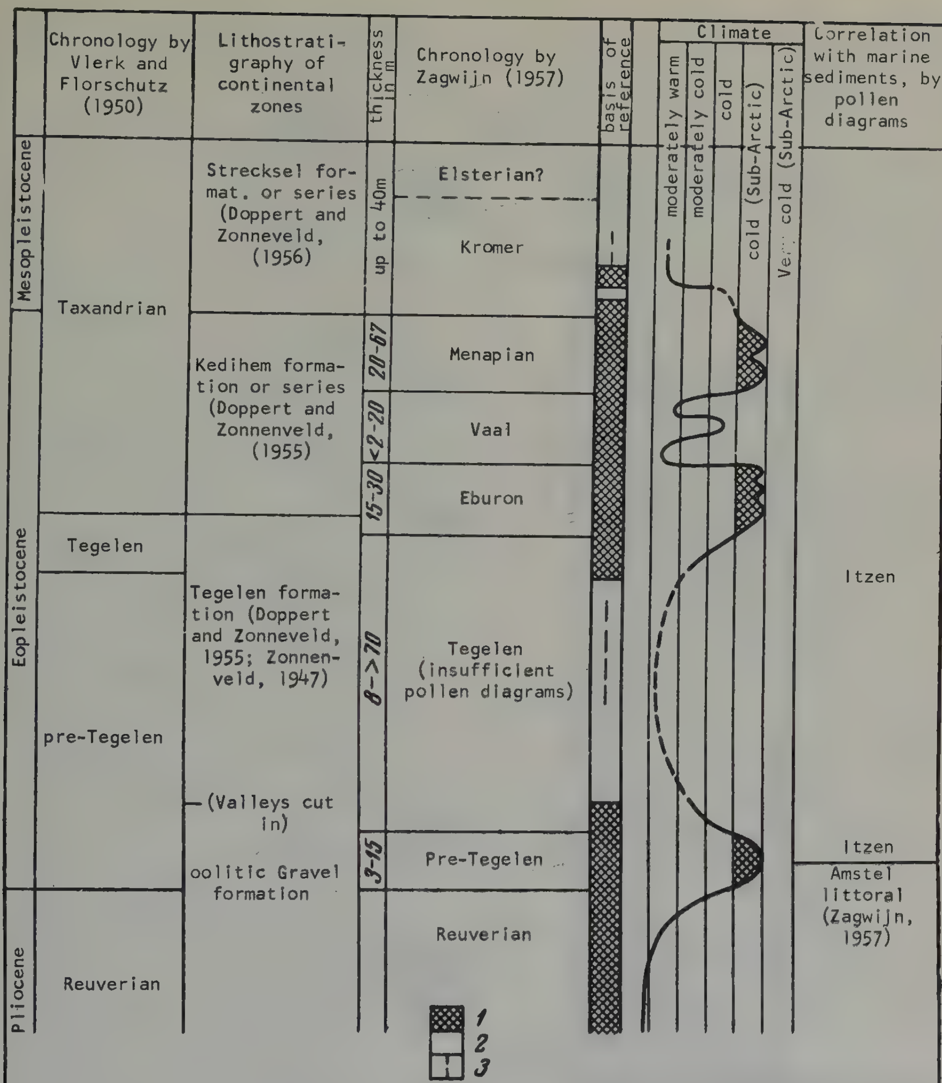

FIGURE 10. Correlation and differentiation of Pliocene-Pleistocene of the Netherlands; after W. Zagwijn [48].

well as with glacial and interglacial Pleistocene periods[11] (in its new meaning) offers a hope that a more rapid and better understanding of Pleistocene history will be gained by a study of deep oceanic oozes than by our painstaking search for truth among continental and shallow marine deposits.

Closed interior basins, such as the Black Sea, whose salinity and fauna have been related to the level of the universal ocean (in turn eustatically related to the climate of the earth), may also yield valuable and complete material on glaciations. However, the thickness of their Quaternary deposits probably exceeds the technical means of taking continuous cores, even from the calmest and deepest parts of a sea. Nevertheless, a comprehensive study of bottom cores from the Black Sea, of a length as great as possible, would be very valuable in the knowledge of the Pleistocene.

[11]See also works of N.A. Belov and N.N. Lapina (in Dokl. AN S.S.S.R, t. 122, no. 1, 1958) A.I. Moskvitin [14], and D.I. Shcheerbakov [24].

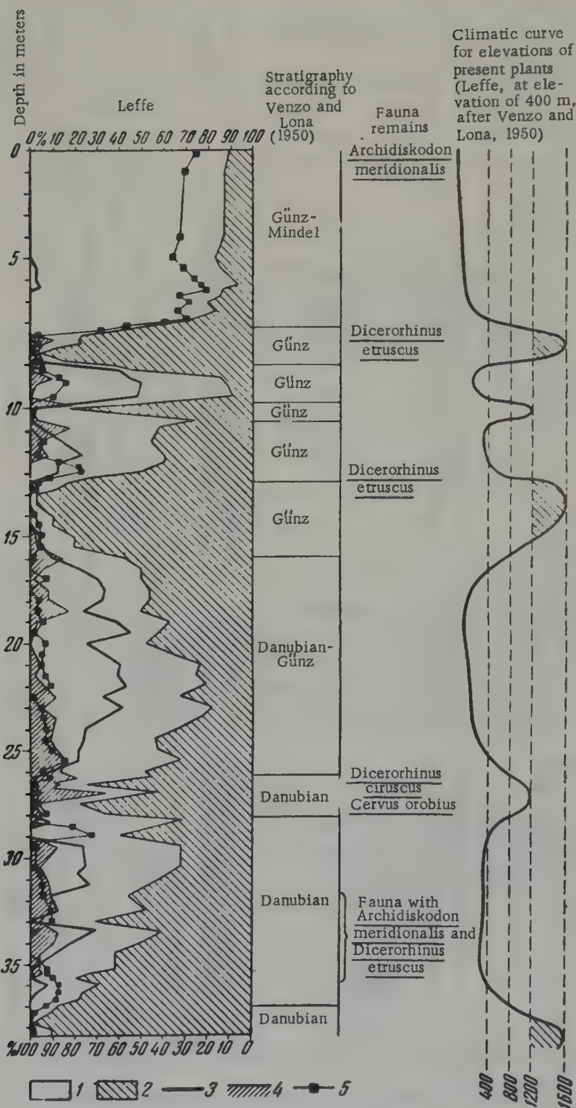

FIGURE 11. Pollen diagram for the Leffe brown coal mines (North Italy).

1) all other trees; 2) Pinus + Betula + Salix; 3) Carya + Pterocarya + Juglans; 4) Tsuga; 5) Quersetum mixtum.

REFERENCES

1. Vostryakov, A.V., N.V. Mizinov, A.I. Moskvitin and A.A. Chiguryayeva, Klimaticheskiye usloviya Akchagyla po novym litologicheskim i mikropaleobotanicheskim isseldovaniyam v yuzhnom Zavolzh'ye. [CLIMATIC CONDITIONS OF THE AKCHAGYL FROM NEW LITHOLOGIC AND MICROPALEOBOTANIC STUDY IN THE SOUTH TRANS-VOLGA REGION]: Dokl. AN SSSR, t. 105, no. 1, 1955.

2. Goretskiy, G.I., O nizhney granitse chetvertichnogo perioda. [THE LOWER BOUNDARY OF THE QUATERNARY]: Byull. MOIP, Otd. Geol., t. 31(4), 1956.

3. Gromov, V.I., I.I. Krasnov and K.V. Nikiforov, Osnovnyye printsipy stratigraficheskogo podrazdeleniya chetvertichnoy sistemy i yeye nizhnyaya granitsa. [BASIC PRINCIPLES OF STRATIGRAPHIC

SUBDIVISION OF THE QUATERNARY, AND ITS LOWER BOUNDARY]: Izv. AN SSSR, Ser. Geol., no. 5, 1958.

4. Kes', A.S., O severo-zapadnoy granitse akchagyl'skogo morya v Privozh'ye. [NORTHWESTERN BOUNDARY OF THE AKCHAGYL SEA IN THE VOLGA REGION]: Tr. Inst. Geogr. AN SSSR, vyp. 42, 1948.

5. Makhnach, N A., Stratigraficheskoye znacheniye sporovo-pyl'tsevykh spektrov iz pleystotsenovykh otlozheniy Belorussii. [STRATIGRAPHIC SIGNIFICANCE OF SPORE-POLLEN ASSEMBLAGES FROM THE PLEISTOCENE OF BELORUSSIA]: Dokl. AN SSSR, t. 114, no. 3, 1957.

6. Makhnach, A.S., A. Ya. Stefanenko, M.M. Tsapenko and M.F. Kozlov, Kratkiy ocherk geologii Belorussi. [OUTLINE OF GEOLOGY OF BELORUSSIA]: Izd. AN BSSR, 1957.

7. Moskvitin, A.I., O geologicheskikh usloviyakh Avdeyevskoy verkhnepaleolitcheskoy stoyanki. [GEOLOGIC CONDITIONS OF THE AVDEYEVKA UPPER PALEOLITHIC SITE]: In book, Kratk. Soobshch. Inst. Istorii i Mater. Kul'tury AN SSSR o Kodladakh i Polevykh Issl., vyp. 31, 1950.

8. Moskvitin, A.I., Vyurmskaya epokha (neopleystotsen) v yevropeyskoy chasty SSSR. [THE WÜRM EPOCH (NEOPLEISTOCENE) IN THE EUROPEAN PART OF THE USSR]: Izd. AN SSSR, 1950.

9. Moskvitin, A.I., O nizhney granitse pleystotsena po novym dannym. [THE LOWER BOUNDARY OF THE PLEISTOCENE, FROM NEW DATA]: Byull. MOIP, Otd. Geol., t. 31, vyp. 2, 1956.

10. Moskvitin, A.I., O nozhney granitse pleystotsena v Yevrope. [THE LOWER BOUNDARY OF THE PLEISTOCENE IN EUROPE]: Izv. AN SSSR, Ser. Geol., no. 4, 1957.

11. Moskvitin, A.I., Veroyatnyy vozrast pervogo oledeneniya Russkoy ravniny. [PROBABLE AGE OF THE FIRST GLACIATION OF THE RUSSIAN PLAIN]: Byul. MOIP, Otd. Geol., t. 32, vyp. 2, 1957.

12. Moskvitin, A.I., Chetvertichnyye otlozheniya i istoriya formirovaniya doliny r. Volgi v yeye srednem techenii. [QUATERNARY DEPOSITS AND THE HISTORY OF FORMATION OF THE MIDDLE COURSE OF THE VOLGA VALLEY]: Tr. Geol. Inst. AN SSSR, vyp. 12, 1958.

13. Moskvitin, A.I., K voprosu o vozrasti i proiskhozhdenii yergeninskoy tolshchi [ON THE AGE AND ORIGIN OF THE YERGENI SEQUENCE]: Byul. MOIP, t. 33, vyp. 6, 1958.

14. Moskvitin, A.I., Sovremennyye predstavleniya o stratigraficheskom delenii i dlitel'nosti pleystotsena. [MODERN CONCEPTS ON STRATIGRAPHIC SUBDIVISION AND THE DURATION OF THE PLEISTOCENE]: Byul. Komis. po Izuch. Chetvert. Perioda, no. 23, 1959.

15. Moskvitin, A.I., Opyt primeneniya yedinoy stratigraficheskoy shkaly k chetvertichnym otlozheniyam Zapadnoy Sibiri. [APPLICATION OF A SINGLE STRATIGRAPHIC SCALE TO QUATERNARY DEPOSITS OF WESTERN SIBERIA]: Tr. Geol. Inst. AN SSSR, vyp. 26, 1959.

16. Obruchev, S.V., Khronologiya lednikovykh epokh po probam morskikh gruntov. [CHRONOLOGY OF GLACIAL EPOCHS FROM SEA-BOTTOM CORES]: Priroda, no. 12, 1951.

17. Orlovskiy, V.G., Geologicheskoye stroyeniye Malo-Kabardinskogo khrebta. [GEOLOGIC STRUCTURE OF THE MALO-KABARDINSKIY RANGE]: Poverkhnosty i Nedra, nos. 5-6, 1926.

18. Popov, G.I., Tanaisskiye sloi drevnego Dona. [THE TANAI BEDS OF THE ANCESTRAL DON]: Byul. Komis. po Izucheniyu Chetvert. Perioda, no. 12, 1948.

19. Pryakhin, A.I., Merzlotno-geologicheskiye yavleniya v tretichnykh i chetvertichnykh otlozheniyakh dolin rek Kamy, Vyatki i Beloy. [FROST PHENOMENA IN TERTIARY AND QUATERNARY DEPOSITS OF KAMA, VYATKA, AND BELAYA RIVERS]: Nauchn. Dokl. Vyssh. Shkoly, Geol-Geogr. Nauki, no. 2, 1958.

20. Reyngard, A.L., O vozraste oledeneniy v gornoy gruppe Shakh-Daga na Vostochnom Kavkaze. [THE AGE OF GLACIATION IN THE SHAKH-DAG, EASTERN CAUCASUS]: Tr. Leningr. Ob. Yestestvoisp., t. 15, vyp. 1, 1936.

21. Reyngard, A.L., K probleme stratigrafii lednikovogo perioda Kavkaza. [ON THE GLACIAL STRATIGRAPHY OF THE CAUCASUS]: Tr. Sov. Sektsii Mezhdunar. Assots. po Izuch. Chetvert. Per., vyp. 1, 1937.

22. Rengarten, V.P., Geologicheskiy ocherk rayona Voyenno-Gruzinskoy dorogi [GEOLOGIC SKETCH OF THE VOYENNO-GRUZINSKAYA (GEORGIAN MILITARY) ROAD]: Tr. Vses. Geol-Razv. Ob'yed., vyp. 148, 1932.

23. Tsapenka, M.M. and N.A. Makhnach, Da stratygrafii antrapagena u rayěne Starobina. [ON ANTHROPOGENE STRATIGRAPHY IN THE STAROBIN AREA]: Vestsi AN BSSR, no. 1, 1957.

24. Shcherbakov, D.I., Shkala geologicheskogo vremenii. [A GEOLOGIC TIME SCALE]: Priroda, no. 7, 1952.

25. Arrhenius G., Sediment cores from the East Pacific. Repts. Swedish Deep-Sea Expedition 1947-1948, vol. 5. Götberg, 1952.

26. Bahr, A., Frostgestauchte Böden im westlichen Schleswig-Holstein. Z. Dtsch. geol. Ges., Bd. 84, 1932.

27. Brelie, G.V.D., u. Rein, U., Pollenanalaytische Untersuchungen zur Gliederungdes Pleistozäns am linken Niederrhein. Geol. en mijnbouw (N.S.), Jg. 18, no. 12, 1956.

28. Doppert, J.W. and J.I.S. Zonneveld, Over de stratigrafie van het fluviatille Pleistoceen in W. Nederland en Noord-Brabant. Meded. Geol. Sticht. (N.S.), no. 8, 1955.

29. Florschütz, F., The subdivisions of the Middle and Young Pleistocene up to the late-glacial in the Netherlands, England and Germany, mainly based on the results of paleobotanical investigations. Geol. en mijnbouw (N.S.), Jg. 19, no. 7, 1957

30. Hough, J.L., Pleistocene lithology of Antarctic ocean-bottom sediments. J. Geol., vol. 58, no. 3, p950.

31. Hough, J.L., Pleistocene climatic record in a Pacific Ocean core sample. J. Geol. vol. 61, no. 3, 1953.

32. Sluijs G. and G. Kortenbout, The cryoturbations in the Tegelen region. Geol. en mijnbouw, Jg. 18, no. 12, 1956.

33. Lona F., Contributi alla storia della begetazione e del clima nella Val Padana. Analisi pollinica del giacimento Villafranchiano di Leffe (Bergamo). Atti. soc. Ital. sci. nat., vol. 89, 1950.

34. Ovey, C.D., Note on the evidence for climatic changes from sub-oceanic cores. Weather, vol. 4, no. 4, 1949.

35. Ovey, C.D., Preliminary results form the study of an ocean core obtained by the Swedish Deep-Sea Expedition, 1947-1948. J. Glaciol., vol. 1, no. 7, 1950.

36. Quitzow, H.W., Die Terrassengliederung im Niederrheinischen Tieflande. Geol. en mijnbouw (N.S.), Jg. 18, no. 12, 1956. Symposium: Das Quatär an Maas und Niederrhein.

37. Rein, U., Pollenanalytische Untersuchungen zur Pliozän-Pleistozängrenze am linken Niederrhein. Geol. Jahrb., Bd. 65, 1951.

38. Straaten, L.M. J.U. van. Structural features of the «Papzand» formation at Tegelen (Netherlands). Geol. en mijnbouw, (N.S.), Jg. 18, no. 12, 1956.

39. Venzo S., Ritrovamento di Anancus arvernensis nel Villafranchiano dell'Adda di Paderno, di Archidiscodon meridionalis e Cervus a Leffe. Stratigrafia e clima del Villafranchiane bergamasco. Atti soc. Ital. sci. nat., vol. 89, 1950.

40. Venzo S. Geomorphologische Aufnahme des Pleistozäns (Villafranchian-Würm) im Bergamasker Gebiet und in der östlichen brianza: Stratigraphie, Paläontologie und Klima. Geol. Rundschau. Bd. 40, H. 1, 1952.

41. Vialli, V., Sul Rinoceronte e l'Elephante dei livelli superiori della serie lacustre di Leffe (Bergamo). Met. Sec. Jt. Sc. Natur., vol. 12, fasc. 1, 1956.

42. Vlerk, J.M., van der. Conclusion, Geol. en mijnbouw (N.S.), Jg. 19, no. 7, 1957.

43. Wunstorf, W., Fliegel G. Die Geologie des Niederrheinischen Tieflandes. Abhandl. Preuss. geol. Landesanst. N.F. 67, 1910.

44. Wolters, R., Nachweis der Günz Eiszeit und der Günz-Mindel--Wärmezwischenzeit am Niederrhein. Geol. Jahrb., Bd. 65, 1951.

45. Wolters, R., Die Günz-Eiszeit am Niederrhein. Z. Dtsch. geol. Ges., Bd. 103, 1952.

46. Wolters, R., Ausbildung und Lagerund der pliozän pleistozänenGrenzschichten im niederrheinischen Grenzgebiet von Niederkrüchten Brüggen. Geol. Jahrb., Bd.69, 1955.

47. Zagwijn, W.H., Zum heutigen Stand der pollenanalytischen Untersuchungen des Pleistozäns in den Niederlanden. Geol. en mijnbouw, Jb. 18, no. 12, 1956. Symposium: Das Quartär an Maass und Niederrhein.

48. Zagwinj, W.H., Vegetation, climate and time-correlations in the early pleistocene of Europe. Geol. en mijnbouw, Jb. 19. no. 17, 1957.

49. Zonneveld, J.I.S., Das Quartär des Südöstlichen Niederlande. Geol. en mijn-bouw (N.S.), Jg., 18, no. 12, 1956.

50. Zonneveld, J.I.S., River terraces and quarternary chronology in the Netherlandes. Geol. en minjbouw, Jg. 19, no. 7, 1957.

Geological Institute of the
USSR Academy of Sciences,
Moscow

Received, March 25, 1959

ANCIENT SHORELINES
OF THE BLACK SEA ALONG THE CAUCASIAN COAST[1]

by

P. V. Fedorov

Marine terraces along the Black and Azov Seas coast have long attracted the attention of scientists. They have been studied by N. I. Andrusov [1, 2, 3] etc.), A. D. Arkhangel'skiy and N. M. Strakhov [4], A.P. Pavlov [15], V. V. Bogachev [6], I. I. Babkov [5], N. B. Vassoyevich [8], M. I. Varentsov [7], N. A. Grigorovich-Berezovskiy [10, 11], V. I. Gromov [12], A. I. Moskvitin [13] ff.), M. V. Muratov [14], G. I. Popov [16], G. I. Goretskiy [9], Ye. V. Shantser [19], A. G. Eberzin [20, 21, 22], and many others.

Without citing details of this study, we only note that, as a result, data have been obtained on the distribution, elevation, and age of the Black Sea terraces.

As of now, the Chaudinsk (or Chaudinsk-Baku), Ancient-Euxinian, Uzunlar, Karangat, and Neo Black Sea[2] terraces are known from the Black Sea shores. The Neo-Euxinian basin coast line is below the Black Sea level. The statement of A. G. Eberzin and P. I. Ivchenko [2] to the effect that this terrace lies above sea level has not been substantiated by recent study.

Most of the above-named authors dealt only with separate segments of the coast whose terraces were not tied into a single system for the entire Soviet Black Sea coast.

This paper, without any claims for completeness, and presenting a generalization of data obtained in the 1953, 1955, 1957, and 1958[3] studies is an attempt to give an over-all picture of terraces along the Caucasian coast.

The oldest Quaternary terrace on the Black Sea coast is associated with the Chaudinsk brackish-water basin, correctly named the Chaudinsk-Baku, by G. I. Popov [16]. This terrace has been considerably denuded and is standing only in isolated remnants, specifically on the south shore of the Kerch Peninsula.

Here it represents an erosion surface truncating dislocated Paleogene clays. The thickness of the Chaudinsk deposits attains several meters. They are split into two parts by loess-like loan: the lower, arenoargillaceous, with a fauna of Didacna parvula Nal., D. baeri-crassa Pavl., and Paludina; and the upper, a coquina bed with Didacna pseudocrassa Pavl., D. rudis Nal., D. tschaudae Andrus., D. cardiotoides Andrus., D. pallasi Pav., and D. eulachia Fed. (Bog.). The height of the coast line at this terrace is about 25 m.

It appears to be possible to agree with the earlier students [2, 14] that remnants of the highest proluvial terrace surface, 160 m high, in the Sudak area, are Chaudinsk. The Chaudinsk terrace is 40 to 45 m high in the Litvinov Point area, the northwest part of the Taman Peninsula (on the coast). Sand deposits, several meters thick, with Didacna parvula Nal., D. baeri-crassa Pavl., Paludina, and Unio, rest here on an eroded surface of Lower Sarmatian clay.

According to A. G. Eberzin [22], loam of the west coast of the Taman Peninsula, south of Point Tuzla, about 10 m thick, are underlain by a conglomerate bed, 1 to 2 m thick, with fragments of Chaudinsk and older (Kimmerian) shells. However, the presence of the Chaudinsk Didacna fragments is only an indirect evidence of the Chaudinsk age of these deposits, because a redeposited fossils may be present in younger deposits.

The Chaudinsk-Baku terrace is fairly

---

[1]Drevniye beregovyye linii Chernogo morya na poberezh'ye Kavkaza.

[2]In preceding works, this terrace was called Ancient-Black Sea. Our 1956-1957 study has made it necessary to rename it the Neo-Black Sea.

[3]The 1953 work was carried on according to a plan of the Oceanology Institute, the U.S.S.R. Academy of Sciences; the 1955-1958 work, according to a Geological Institute of the U.S.S.R. of Sciences plan.

widely distributed along the Caucasian coast, although it is considerably broken up by erosion and denudation. It has been observed usually southeast of Dzhubga [12, 13, 14, 19].

This is the highest marine terrace along the coast (95 to 110 m), not counting the dismembered terrace surfaces in the estuarine areas of large rivers (Gumista, Kodar, etc.), apparently Pliocene.

In the summer of 1958, we succeeded in discovering a Chaudinsk terrace northwest of the Pshada mouth, in the area of Idukopas Point. Here, truncated and steeply dipping flysch beds are overlain by conglomerate and detrital limestone, 2 to 3 m thick, with a fossil assemblage (usually impressions and fragments) of Didacna cf. rudis Nal., D. pseudocrassa Pavl., D. cf. parvula Nal., D. tschaudae Andrus., D. pleistopleura Davit., Dreissens, and Teodoxus.

The top of these deposits stands 45 m high. Considering the width of the terrace, it may be assumed that its ancient coastline stood about 50 m high.

Southeast of Tuapse, remnants of the Chaudinsk terrace, about 100 m high, are seen along almost the entire coast, as far as the mouth of Kodor River. A fossil assemblage from this terrace is known only from the Sukhumi area [12]. A fossiliferous Chaudinsk terrace, of the same height of 100 m, is developed in Guriya, i. e., in the foothills of the Little Caucasus.

Thus, definite regularities in the position of this terrace are present along the Caucasian coast.

First, its height remains at practically the same level of about 100 m, along the entire coastline from Tuapse to the mouth of the Kodor.

Secondly, there is no gradual transition between this stretch of coast and that at Idukopas Point where the terrace is 50 m high. It is quite probable that this break in the Chaudinsk coastline is related to a definite structural break marking a change from the Caucasian uplift zone to that of the western Caucasian foredeep, not as a gradual subsidence but as one or several faults.

Third, the complete similarity in elevations of the Chaudinsk coastline within the Greater and Little Caucasus is quite striking.

It is interesting that similar features are characteristic of the Baku terrace on the Caspian side of the Caucasus [17, 18], except that the latter is much higher, attaining 250 m.

The Ancient-Euxinian terrace of the Black Sea is much better preserved. To be sure, on the Kerch and Taman peninsulas it is overlain by younger Uzunlar and Karangat deposits, has no morphologic expression, and stands only a few meters high above sea level. In the Caucasus, however, from the mouth of the Pshada and as far as Sukhumi, it is quite conspicuous. It is represented by conglomerate, detrital limestone, and sandstone, less commonly by argillaceous sands, total thickness 1 to 3 m, resting on dislocated and eroded basement rocks and carrying a fossil assemblage of Didacna nalivkini Wass., D. pseudocrassa, etc.

Between the Pshada mouth and Beskrovnyy Point the Ancient-Euxinian coast line is 40 to 42 m high, with 60 m high southeast of Point Agriya and as far as Sukhumi.

Thus the Ancient-Euxinian terrace, like the Chaudinsk, is uniformly high between Tuapse and Sukhumi. Northwest of Tuapse, it forms a bench in its longitudinal section and stands 40 to 42 m high. The depressed stretch of the Ancient-Euxinian terrace is overlain by littoral Uznular deposits, at an elevation of 30 to 35 m; this is especially noticeable east of the Pshada mouth (between Krinitsa and Betta villages) where detrital limestone with intercalations of a pebble conglomerate and a Didacna nalivkini Wass. assemblage are overlain by coarser conglomerate with Cardium edule L. The latter are developed in a rather narrow band along the terrace edge, on the sea side, while Ancient-Euxinian limestone, changing to coarse conglomerate inland, cover the entire width of the terrace. The superposition of Uzunlur deposits on the Ancient-Euxinian terrace has been observed southeast of Dzhubga, at Tenginka village[4].

Southeast of Point Agriya and as far as the Kodor mouth, the Uzunlur terrace is traceable at an elevation of about 40 m. It maintains this height farther on, along the Little Caucasus and Guriya coast.

Only in a small segment Ashe-Makopse (southeast of Tuapse) did we observe this terrace at an elevation of 42 to 45 m, which is connected with local uplift on a background of the general and very gradual rise of the coast as reflected in the striking consistency of the ancient Uzunlar sea coastline. A very curious fact should be noted here - the complete similarity in the elevations of the Uzunlar terrace in both the Greater and Little Caucasus.

The Uzunlar terrace is one the most characteristic and best defined in the weathered surface relief of the Caucasian coast. It is well preserved almost everywhere southeast of Dzhubga, as far as the mouth of

Kodor River, and in Guriya.

The superposition of the Ancient-Euxinian terrace by Uzunlar deposits, between the mouth of Pshada and Tenginka village, suggests a close stratigraphic relationship between Ancient-Euxinian and Uzunlar beds. At the same time, the presence of two independent terraces, the Ancient-Euxinian and Uzunlar, southeast of Tenginka lends substance to the assumption of a definite break between the 60-m and the 40-m terraces.

The Uzunlar terrace is not expressed morphologically within the Kerch and Taman peninsulas. Here, Uzunlar deposits are buried under Karangat continental to marine deposits and are located 1 to 5 m above sea level. The continental mantle is also characteristic of the Uzunlar terrace along the Caucasian coast.

Karangat (Tyrrhenian) deposits, with their richest fossil assemblage of a Mediterranean fauna, are widely distributed along the Caucasian coast and in the Kerch-Taman area.

Up to recently, only one Karangat terrace, 15 to 29 m high, was identified in the Caucasus [12, 13, 19, 21]. However, our own geomorphologic, stratigraphic, and paleontologic study of the Caucasian coastal terraces gives a basis for identifying two Karangat terraces, a high and a lower one. The high Karangat terrace is mostly erosional, 24 to 26 m high (along the ancient coastline). Its edge is 19 to 20 m high, descending to 16 or 18 m where the terrace is particularly wide (west of the mouth of Agoy River; southwest of Adler, etc.). The lower Karantag terrace is 12 to 14 m high (shoreline). Its foundation is made up of the same basement flysch rocks as that of the high terrace; consequently its formation was preceded by erosion. However, the deposits of this terrace are locally 6 to 8 m thick, while those of the high terrace are 1 to 3 m thick (under the same conditions of an eroded coast).

In the estuarine reaches of the rivers, both terraces are constructional. Contrary to Ye. V. Shantser's view [19], it must be noted that Karangat deposits here do not cover the alluvium; on the contrary, coarse alluvial gravel beds overlie the well-stratified marine sands and gravels.

The richest molluscan fauna is present in deposits of the lower 13-m terrace. It is represented by Cardium tuberculatum L., C. edule L., Tapes calverti Newt., Pecten ponticus Mil., Ostrea taurica Kryn., Venus gallina L., Aporrhais pes pelicani L., Mytilus galloprovincialis Lam., Mactra subtruncata da Costa, Cerithium vulgatum Brug., Nassa reticulata L. A similar fossil assemblage, although not as numerous, is present in deposits of the high Karangat terrace. We have collected Cardium tuberculatum L. and Tapes calverti Newt. in the high terrace, between Khosta and Adler. They are known also from other localities along the coast. For this reason, the low terrace cannot be Surozhian [16]. A terrace near Adler, forming a bench 10 to 11 m. high (or 15 to 16 m. above sea level), and formed by stratified consolidated sands with gravel beds and an improverished Karangat fauna of Venus gallina L. and Donax julianae Kryn., is regarded as Surozhian by G. I. Popov [16] and G. I. Goretskiy [9], because it is lower than the Karangatian and does not contain the typical Karangatian mollusks, Cardium tuberculatum and Tapes calverti Newt.

However, our observations have shown that the terrace rim was lowered artificially by a quarry; in adjacent segments the terrace has its normal height of 24 to 25 m.

About 0.5 to 1 km northwest of there, Cardium tuberculatum L. and Tapes calverti Newt. were collected from deposits of the same terrace. The impoverished molluscan fauna of this terrace at Adler is due to the proximity and freshening effect of the mouth of Mzymta River. Consequently, this terrace is Karangatian rather than Surozhian.

Both Karangat terraces, the high and the low, carry the same Mediterranean (Tyrrhenian) fossil assemblage; biostratigraphically, they are a single unit. The presence of two geomorphologically distinct surfaces - a high one, chiefly erosional, and a low one, chiefly accumulative - is the result of a progressive uplift related to that of the Caucasus; it also may reflect the two phases of a Karangatian marine transgression.

The high Karangat terrace is separated from the Uzunlar surface by an escarpment, 10 to 15 m high. This induced A. D. Arkhangel'skiy and N. M. Strakhov [4] to assume the presence of a break between the Uzunlar and the Karangat brought about, according to them, chiefly by tectonic causes (post-Uzunlar uplifts).

Evidence of a break between the Uzunlar and the Karangat is present also in a number of localities on the Kerch peninsula (Lakes Uzunlar, Tobechik, and Chokrak). Here, Uzunlar and Karangat marine sediments are separated by terrestrial clays.

Karangat deposits on the Kerch and Taman peninsulas form a single body of littoral marine sand and shell beds, less commonly of clay, not differentiated by appreciable breaks. To be sure, there is at least one erosional surface in the Karangat section,

in the area of Karangat Point and along the coast north of Tobechi Lake, but it is the boundary between two facies rather than a stratigraphic break.

The Karantag (Tyrrhenian) terrace is morphologically poorly expressed along the shores of the Kerch and Taman peninsulas because it is overlain there by fairly thick (up to 10 to 12 m) loess-like loams. The thickness of Karangat deposits ranges here from one to seven meters, with an ancient shore line suggested at 5 to 8 m.

The formation of the Lower Karangat terrace was followed by a deep incision of all river valleys in their estuatine reaches, caused by a post-Karangat regression of the Black Sea and by the Caucasian uplifts.

The contemporaneous basin outlines were near the present water level, below sea level. The Surozhian terrace, discovered by G. I. Popov [16] and corresponding, according to him, to a marine transgression prior to the Neo-Euxinian regression, has not been observed by this author along the Black and Azov Seas coast. A low terrace, 3 to 5 m high, referred to by G. I. Popov, turned out to be Holocene (Neo-Black Sea).

Thus, traces of the Black Sea coastlines,. during a time interval between the formation of the 13-meter (lower) Karangat and Neo-Black Sea terraces, lie below the water and are lacking along the coast.

Judging from the degree of dismemberment (preservation) of the Karangat terraces, their differentiation (the Caucasus and the Kerch-Taman area), the depth of post-Karangat cutting of river valleys, the thickness of overlying loam on Karangat deposits in the Azov region, and other data, that time interval was fairly long; we believe that it embraced almost all of the Late Quaternary.

A Neo-Black Sea terrace appears along the Caucasian coast and along the shores of the Kerch and Taman peninsulas. It is developed especially well along the Azov shore of the Kerch peninsula, east of Kazantip Point, on the south Crimean shore; and in the Caucasus, southeast of Khosty. The shoreline of this terrace is 3 to 5 m high. On coastal stretches protected by promontories or by large shoals, where the modern surf in storm does not rise higher than one meter, the terrace usually is 3 m high, with 5 m on unsheltered stretches. The latter is true for the entire Caucasian coast. In view of the above, it can be assumed that the Neo-Black Sea coastline has not undergone deformation.

Deposits of the Neo-Black Sea terrace carry a Mediterranean-type faunal assemblage, somewhat more adapted to salt water than the present fauna. Present here are Cardium edule L., Venus gallina, L., Nassa reticulata L., Solen marginatus Penn., Ostrea taurica Kryn , and Pecten ponticus Mil On the basis of a finding of remains of the Koban' culture, V. I. Gromov assigns the Abkhazian segment to the Bronze Age [12]. We concur with that dating [18].

The Neo-Black Sea terrace corresponds to the Nice terrace of the Mediterranean, of the same height of 4 to 5 m.

D. Yaranov, a Bulgarian geologist (oral communications), has observed an erosional terrace, about 5 m high, on the north Aegean coast. Pumice pebbles were found in it along with those of other rocks. D. Yaranov believes that this pumice is related to the eruption of one of the Mediterranean volcanos, which took place in the second millenium of our era.

Thus the age of this terrace, in both the Black Sea and the Mediterranean regions, is approximately the same, falling into the second millenium before our era.

Very recently we have succeeded in discovering a still younger terrace, the Nymphean [18], whose deposits overlie recent loam with artifacts of ancient Greek colonies on the Black Sea shores (Fourth century B. C. to the First or Second centuries A. D.).

The Nymphean terrace, 1.5 to 2 m high, has been found, up to the time, only on the east shore of the Kerch Peninsula and in the Batumi area. A broad terrace, about 2 m high, between Anapa and the Vityazevskiy liman also appears to be related to the Nymphean marine transgression. The age of that terrace is fairly definite; it began to form after the third century A. D., which has been proven by the fact that its marine deposits are overlain by terrestrial loam with culture horizons of the town of Nymphea which persisted into early centuries of our era.

Along the Caucasian coast, most of these marine terraces are correlative with terraces of major rivers of the west Caucasian slope (Kodor, Gumista, Shakhe, Pshada, etc.). Thus the 100-meter Chaudinsk terrace corresponds to river terrace V; the 40-meter Uzunlar terrace, to terrace IV; the high Karantag terrace (25 m), to river terrace III; the lower Karantag (12 to 14 m), to terrace II; and the Neo-Black Sea terrace, to river terrace I. Correlation of the 60-meter Ancient-Euxinian terrace is not quite clear.

Considering the stratigraphic similarity of Ancient-Euxinian and Uzunlar marine deposits and of a break between them, it can be assumed

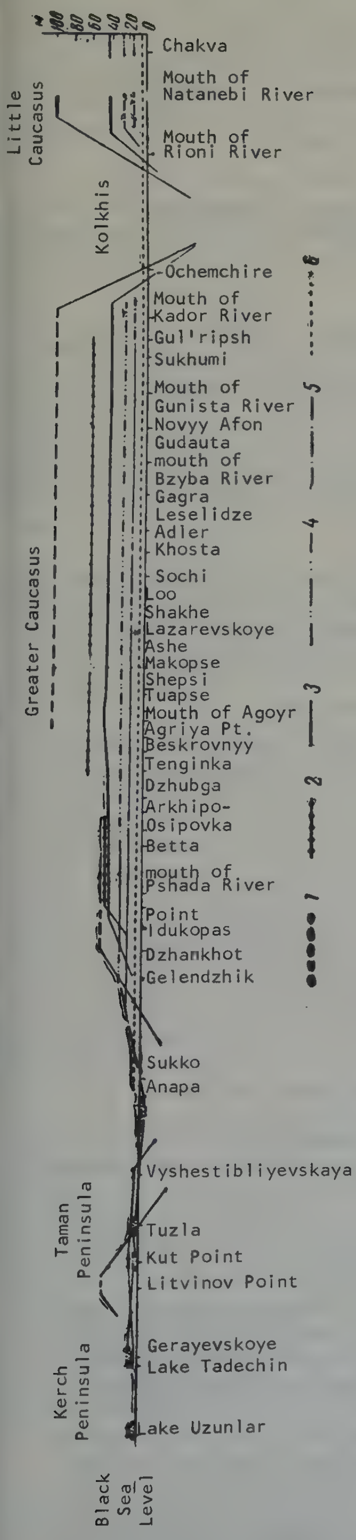

Diagram of deformation in the ancient shorelines of marine terraces of northeastern coast of the Black Sea (from Kerch Peninsula to Batum).

Coastlines: 1) Chaudinsk; 2) Ancient-Euxinian; 3) Uzunlar; 4) Karangat, high; 5) Karangat, lower; 6) Neo-Black Sea.

that river terrace IV (particularly that of the Kodor) was formed in two stages, the Ancient Euxinian and the Uzunlar and its present morphologic features were shaped in Uzunlar and post-Uzunlar time.

The relationship of marine and river terraces in estuarine areas is characterized by superposition of alluvial deposits of a river terrace on the corresponding marine terrace. This can be observed for the Ancient-Euxinian and the Uzunlar terraces at the mouths of Pshada, Shakhe, Gumista, and other rivers; at the Karangat marine and river terraces III and II; the estuarine area of Mzymta, Supsa (Guriya) rivers, etc.

Thus the surface of each river terrace was formed somewhat later than that of the corresponding marine terrace, during the initial stages of a marine regression, where deltaic and alluvial deposits were progressively overlapping the marine.

In considering marine terraces of the Caucasian coast, we cannot overlook their relationship with glacial formations.

A terminal moraine discovered by V. P. Rengarten, Ye. V. Shantser [19], and others in the Amtkhel valley (right tributary of the Kodor), in 1958, was also inspected by A. R. Geptner and the author.

Data from aerial photographs and from careful personal observations corroborate the two authors' statement to the effect that segments of a terminal moraine remain standing on the right bank of the Amtkhel, below its confluence with Dzhampol River. The most obvious remnant is located on the left bank of the Amtkhel.

At the base of a morainal hill, 380 to 400 m high, there are small dislocations in strongly plicated underlying Paleogene and Upper Cretaceous rocks due to glaciation; above that, there is a typical morainal development of boulders, chunks of rocks, and silt. Adjoining the outer side of the moraine are outwash sands.

Down the Amtkhel, at its confluence with the Kondor, there is a terrace standing 120 to 125 m above the river (310 to 315 m above sea level). This terrace is correlated with the Kodor terrace IV. We believe that alluvium of the latter terrace is somewhat older than the terminal moraine and corresponds to the initial advance of an ice tongue down the Amtkhel valley. The incision of terrace IV by the river coincides with the maximum spread of the glacier and with the formation of the terminal moraine. A. R. Geptner believes that correlation of terrace IV and the terminal moraine is more correct.

Relationship of Marine Terraces of the Black and the Caspian Seas with the Mediterranean Terraces

Mediterranean (after F. Zeuner, [23])	Black Sea	River Terraces of Western Caucasus	Caspian Sea	Volga Terraces
Modern beds	Nymphean terrace (2 m)	Flood plain		
Break	Break	Incision	Neo-Caspian terrace (22 m)	Floodplain
Flandrian (Nizza) terrace	Neo-Black Sea terrace (5 m)	Terrace I		
	Ancient-Black sea stage	Beginning of accum. of terrace I	Mangyshalk stage	Incision
			Upper Khvalynsk terraces (--16, -11, -2)	Terrace I
	Neo-Euxinian stage Transgression		Break	Deep incision
		Deep incision	Lower Khvalynsk terrace (22 to 25 m)	Terrace II
Break				
	Regression		Break	Incision
			Lower Khvalynsk maximum terrace (48 m)	Terraces III and IV
Tyrrhenian II: Late Monasterian terrace	Lower Karangat (13 m) terrace	Terrace II	Break	Deep Incision
	Break	Incision	Upper Khazarian terrace (-40 to -50 m in the Caucasus)	
Tyrrhenian II: Main Monasterian terrace	High Karangat (25 m)	Terrace III		
Break	Break	Incision	Break	
Tyrrhenian (I)	Uzunlar (40 m)	Terrace IV		
	Ancient Euxinian (60 and 40 m)		Lower Khazarian terraces (85, 125, and 160 m, in the Caucasus)	
Milazzian?	Break	Incision	Break	
Sicilian?	Chaudinsk terrace (100 m)	Terrace V	Upper Baku terrace in the Caucasus (250 m)	

Thus, the Uzunlar marine terrace, overlain by alluvium of terrace IV in the estuarine area of the Amtkhel, is older than the terminal moraine of that valley, which, in turn, is usually correlated with the maximum Quaternary glaciation in the Caucasus. This corroborates the view of Ye. V. Shantser [19] and V. I. Gromov [12].

In considering the degree of deformation in ancient coastlines of the Black Sea, (see diagram), the following generalizations can be noted:

1. The older the terrace, the greater its vertical displacement.

2. All terraces along the Caucasian coast (except for the Neo-Black Sea) have been uplifted uniformly, without a change in slope (especially southeast of Tenginka village).

3. The magnitude of the uplift is exactly the same for the Greater and the Little Caucasus.

4. The regions of uplifts (the Caucasus) are separated from subsidences (Kuban and

Rion plains) not by a gradual transition but by an abrupt break in the elevations of ancient terraces, evidently reflecting a deep fault or a system of faults. A definite asymmetry is present: the plunge of the Caucasus toward the Kuban plain occurs in two (perhaps three) steps; its plunge toward the Rion plain is a single step.

5. A latitudinally asymmetric uplift of the Caucasus is demonstrated by comparing the deformation diagram with our deformation diagram for the Caspian terraces along the Caucasian coast [17].

Thus, while the Chaudinsk terrace has been raised 100 m, on the Black Sea Caucasian coast, the contemporaneous Baku terrace has been raised 250 m in Dagestan and North Azerbaydzhan, on the Caspian coast. In this computation, the level of the Chaudinsk and the Baku seas is assumed to be the same, on the basis of stratigraphic and paleontologic data.

A similar picture emerges from the comparison of contemporaneous coastlines of the Ancient-Euxinian and Lower Khazarian seas: the first one stands 60 m high in the Caucasus, while the second stands 160 and 125 m in the Eastern Caucasus.

The striking consistency of the Black Sea terraces at elevations of 5, 13, 25, 40, 60, and 100 m, along a considerable stretch of the Caucasian coast, implies the existence of a Caucasian system of ancient coastlines of the Black Sea, as well as of a Caucasian system of similar Caspian coastlines developed at elevations of -22 (6), -16 (12), -11 (17), -2 (26), 14 (42), 25 (53), 47 (75), 85 (113), 125 (153), 160 (188), and 250 (278) m. In this system, all Caspian coastlines, from -22 (6) m, to 47 (75) m, inclusively, and belonging to the Khvalynsk and the Neo-Caspian, are characteristic for the entire Caspian coast, and not for the Caucasus alone.

A comparison of the Black Sea Caucasian terraces with the Mediterranean reveals a great similarity in their heights (5, 13, 25, 40, 60, and 100 m). However, only the first four terraces are comparable, not only in their height but in fossil content, as well. Thus the 5-meter Neo-Black Sea terrace corresponds to the Mediterranean Nizza (Nice) terrace; the two Karangat terraces (13 and 25 m) are correlative faunally with the Tyrrhenian III terrace; and the 40-m. Uzunlar terrace probably corresponds to the Tyrrhenian I.

Despite the great similarity of surface of the Ancient-Euxinian (60 m) and Chaudinsk (100 m.) Black Sea terraces and the Mediterranean Milazzian (60 m) and Sicilian (100) terraces, there are no data on their correlation, as yet. A correlation of the Black and the Caspian Seas terraces and their possible relationship with Mediterranean terraces, as based on material at hand, is presented in a table above.

REFERENCES

1. Andrusov, N.I., O vozraste morskikh posletretichnykh terras Kerchenskogo poluostrova. [THE AGE OF POST-TERTIARY MARINE TERRACES IN THE KERCH PENINSULA]. Yezhegodn. Geol. i Mineralog. Rossii., t. 7, vyp. 6, 1905.

2. Andrusov, N.I., Terrasy Sudaka. [THE SUDAK TERRACES]. Zap. Kiev. Ob. Yestestv. t. 22, vyp. 2, 1912.

3. Andrusov, N.I., Posletretichnaya tirrenskaya terraca v oblasti Chernogo Morya. [A POST-TERTIARY TYRRHENIAN TERRACE IN THE BLACK SEA REGION]. Bull. Intern. de l'Academie des Sc. de Boheme, 1925.

4. Arkhangel'skiy, A.D. and N.M. Strakhov, Geologicheskoye stroyeniye i istoriya razvitiya Chernogo morya. [GEOLOGIC STRUCTURE AND THE HISTORY OF DEVELOPMENT OF THE BLACK SEA]. Izd. AN SSSR, 1938.

5. Babkov, I.I., Morskiye posletretichnyye terrasy i rakovinnyye skopleniya po beregam Kryma. [POST-TERTIARY MARINE TERRACES AND SHELL ACCUMULATIONS ALONG THE CRIMEAN SHORES]. Priroda, No. 6, 1929.

6. Bogachev, V.V., Stepi basseyna Manycha. [STEPPS OF THE MANYCH BASIN]. Izv. Geol. Kom., t. 17, No. 2, 1903.

7. Varentsov, M.I., Geologicheskaya istoriya Tamanskogo poluostrova v posletretichnoye vremya. [GEOLOGIC HISTORY OF THE TAMAN PENINSULA IN POST-TERTIARY TIME]. Tr. II Mezhdunar. Assots. po Izuch. Chetv. Per. Yevropy, vyp. 3, 1933.

8. Vassoyevich, N.B., O drevnekaspiyskikh otlozheniyakh na Tamanskom poluostrove. [ANCIENT CASPIAN DEPOSITS ON THE TAMAN PENINSULA]. Azerb. Neft. Khoz. No. 8-9, 1928.

9. Goretskiy, G.I., O paleogeografii Priazov'ya i Zapadnogo Primanych'ya v Uzun-Larsko-Girkanskiy i Burtasskiy veka. [PALEOGEOGRAPHY OF THE AZOV AND WEST MANYCH REGIONS

IN THE UZUNLAR-HYRCANIAN AND BURTAS AGES]. Vopr. Geogr., sb. 33, 1953.

10. Grigorovich-Berezovskiy, N. A., Post-pliotsenovyye morskiye otlozheniya Chernomorskogo poberexh'ya. [POST-PLIOCENE MARINE DEPOSITS OF THE BLACK SEA COAST]. Zap. Novoross. Ob. Yestestvoisp., t. 24, vyp. 2, 1902.

11. Grigorovich-Berezovskiy, N. A., Post-pliotsenovyye otlozheniya kaspiyskogo tipa v Chernomorskoy gubernii. [POST-PLIOCENE DEPOSITS OF THE CASPIAN TYPE IN THE CHERNOMORSKAYA GUBERNIYA]. Ibid., t. 25, vyp. 1, 1903.

12. Gromov, V. I., Paleontologicheskoye i arkheologicheskoye obosnovaniye stratigrafii kontinental'nykh otlozheniy chetvertichnogo perioda na territorii SSSR (mlekopitayushchiye, paleolit). [PALEONTOLOGIC AND ARCHAEOLOGIC SUBSTANTIATION OF QUATERNARY DEPOSITS IN THE USSR (MAMMALS, PALEOLITHIC ARTIFACTS)]. Izd. AN SSSR, 1948.

13. Moskvitin, A. I., Lednikovyye obrazovaniya Krasnoy Polyany, terrasy r. Mzymty i chasti Chernomorskogo poberezh'ya Kavkaza. [GLACIAL FORMATIONS OF KRASNAYA POLYANA, THE MZYMTA RIVER TERRACE, AND A SEGMENT OF THE CAUCASIAN BLACK SEA COAST]. Byul. Komis. po Izuch. Chetv. Perioda, No. 4, 1938.

14. Muratov, M. V., Istoriya Chernomorskogo basseyna v svyazi s razvitiyem okruzhayushchikh yego oblastey. [HISTORY OF THE BLACK SEA BASIN IN CONNECTION WITH THE DEVELOPMENT OF THE SURROUNDING PROVINCES]. Byul. MOIP, Otd. Geol., t. 26, vyp. 1, 1951.

15. Pavlov, A. P., Neogenovyye i posletretichnyye otlozheniya Yuzhnoy i Vostochnoy Yevropy. [NEOGENE AND POST-TERTIARY DEPOSITS OF SOUTHERN AND WESTERN EUROPE]. Sravnitel'naya Stratigrafiya Presnovodnykh Otlozheniy. Moscow, 1925.

16. Popov, G. I., Istoriya Manychskogo proliva v svyazi so stratigrafiyey chernomorskikh i kaspiyskikh chetvertichnykh otlozheniy. [HISTORY OF THE MANYCH STRAIT IN CONNECTION WITH THE DEVELOPMENT OF THE CASPIAN SEA]. Byul. MOIP, t. 30, vyp. 2, 1955.

17. Fedorov, P. V., Stratigrafiya chetvertichnykh otlozheniy i istoriya razvitiya Kaspiyskogo morya. [STRATIGRAPHY OF QUATERNARY DEPOSITS AND THE HISTORY OF DEVELOPMENT OF THE CASPIAN SEA]. Tr. Geol. Inst. AN SSSR, vyp. 10, 1957.

18. Fedorov, P. V., O kolebaniyakh urovnya Chernogo morya v poslelednikovoye vremya. [POST-GLACIAL FLUCTUATIONS OF THE BLACK SEA LEVEL]. Dokl. AN SSSR, t. 124, No. 5, 1959.

19. Shantser, Ye. V., Novoye o terrasakh Chernomorskogo poberez'ya Kavkaza. [NEW DATA ON THE BLACK SEA CAUCASIAN TERRACES]. Tr. Sov. Sekts. Mezhdunar. Assots. no Izuch. Chetvert. Per. Yevropy, vyp. 4, 1939.

20. Eberzin, A. G. and A. S. Vyalov, Drevneevksinskaya terrasa v okrestnostyakh Tuapse. [AN ANCIENT-EUXINIAN TERRACE IN THE VICINITY OF TUAPSE]. Dokl. AN SSSR, t. 2, No. 5, 1936.

21. Eberzin, A. G. and P. I. Ivchenko, Karangatskaya i novoevksinskaya terrasy g. Sochi i yego okrestnostey. [THE KARANGAT AND NEO-EUXINIAN TERRACES OF SOCHI AND VICINITY]. Ibid., t. 56, 1947.

22. Eberzin, A. G., O plastakh chaudy Tamanskogo poluostrova. [CHAUDINSK BEDS IN THE TAMAN PENINSULA]. Ibid., Nos. 8-9, 1935.

23. Zeuner, F. E., Pleistocene shorelines. Geol. Rundshau, BD. 40, H. 1, 1952.

Geological Institute of
the USSSR Academy of Sciences,
Moscow

Received May 5, 1959.

PALEOGEOGRAPHIC POSITION OF THE KIZEL CARBONIFEROUS BASIN AND ITS GENTIC FEATURES IN THE LIGHT OF NEW DATA[1]

by

N. I. Markovskiy

This paper specifies the position of the Kizel basin located between the Russian Platform and the Uralian geosyncline. The main genetic features of the basin are described along with its relationship in position and coal prospects to the petroliferous, terrigenous Lower Carboniferous deposits in the Perm Ural region.

* * * * *

Terrigenous sediments occur nearly everywhere in the Lower Carboniferous section on the Russian Platform. They are underlain by Tournaisian limestone; toward the top, they change gradually to limestone and dolomite of the Visean Tula sequence. The upper part of the Kizel belongs here, and all of the Stalinogorsk or coal-bearing sequence, and the lower part of the Tula sequence.

This terrigenous sequence is represented by an uneven alternation of argillaceous, silty, and arenaceous rocks, considerably enriched in carbonized plant detritus and commonly carrying beds and lenses of coal. In a number of areas, especially along the eastern edge of the platform, the terrigenous sequence is productive not only in coal but in oil and gas as well.

Numerous correlations of sections from different localities of the Ural-Volga region reveal a great similarity in their make-up. The sequence begins and ends with generally argillaceous transitional formations, expressing a change, either conformable or unconformable, from carbonate to argillaceous and arenaceous deposits, and vice versa. These transitional formations are separated by intermediate ones, represented chiefly by sandstone, and by predominantly argillaceous intervals which are mostly coal-bearing. The thickness, the consistency, and the number of such formations are not marked by uniformity.

Paleontologically, this sequence is almost barren; the few index fossils suffest that it is not older than the Chernyshin and no younger than the Yasnaya Polyana. The Lower Visean age of its upper part has been fairly definitely established, both by the fauna and the spore-pollen assemblage. Not definitely determined is the age of its lower part which rests in many places on an eroded surface of older deposits. The most characteristic feature of the entire section is its rather considerable coal content. However, it is a fact that the first oil gusher was drilled in the south of the Kizel basin, at Chusovskiye Gorodki, in 1929, opening up some of the richest oil areas between the Ural and the Volga. It was discovered subsequently that the coal measures also carry oil and gas.

The formation of Lower Carboniferous productive sediments and their fossil fuels is most closely related to the paleotectonic and paleogeographic environment of Tournaisian-Visean time.

To be sure, the original features of this environment are concealed under thick Carboniferous and Permian deposits and have been considerably modified by subsequent geotectonic processes. The ancient structural plan and the geographic environment associated with it can be inferred only from the character of change in the facies and thickness of this terrigenous sequence.

Lithologic features of these rocks indicate that they belong to different facies. Throughout most of the Perm Ural region, they are obviously continental, divisible into two main types, the alluvial-channel and the marsh-lacustrine.

The alluvial deposits, a result of river activity, usually are represented by sandstone and siltstone, alternating with shale and claystone. Their main features are the inconsistency in granulometric composition, the presence of

[1]Paleogeograficheskoye polozheniye Kizelovskogo kamennougol'nogo basseyna i yego geneticheskiye osobennosti v svete noveyshikh dannykh.

non-horizontal bedding, the abundance of plant detritus, and great variations in thickness, both laterally and vertically.

The marsh-lacustrine deposits are mostly carbonaceous shale, siltstone, and less commonly sandstone with intercalations and lentils of coal of different thickness and ash content.

In addition, terrigenous deposits of a different type include thick deltaic formations of the Kizel basin. The latter represented, in Early Carboniferous time, the delta of an immense river. A great accumulation of coal took place in the land portion of this delta, dismembered into isolated islands by tributaries and channels. At the same time, littoral marine conditions of sedimentation prevailed in the east and southeast of the basin where claystone and sandstone alternate with limestone and dolomite locally carrying remains of a euryhaline fauna.

The shelf zone of the marine basin which washed a humid-type alluvial-marsh land supported the submerged part of the delta and witnessed an apparently mass accumulation and burial of plants and organisms. It may be assumed therefore that while coal accumulated over the land portion of this delta, the submarine environment of a Tournaisian-Visean sea provided a site for complex biochemical processes to transform organic substances into liquid and gaseous hydrocarbons. It is not an accident that oil showings, probably of a secondary nature, are not uncommon in the Kizel (coal) shafts.

Consequently, although rocks of this terrigenous sequence are characterized by their different facies, they belong on the whole to continental, and less commonly to shallow marine formations. The continental sediments include numerous coal deposits; widely distributed among the marine sediments are rocks with a high content of organic carbon and bitumens. The latter probably were the source of Carboniferous oil and gas in the Ural-Volga region.

All this makes it possible to regard these Lower Carboniferous terrigenous deposits, although resting locally on different Tournaisian units and even on the Frasnian Devonian, as a single polyfacies body of the same age, formed under different physical and geographic conditions. These conditions were determined by geotectonic and to a considerable extent by climatic factors prevailing at the close of the Tournaisian and the beginning of the Visean.

The marshy lowlands which occupied most of the Russian Platform were washed in the east and southeast by one or more seas. The borderland between the land and the sea was locally cut by the estuaries and deltas of rivers flowing from the continent. Subaerial portions of deltas were thickly overgrown by a lepidophytic flora which penetrated ever deeper into the plain and became concentrated first about freshwater and brackish intracontinental basins.

One of such major deltas is the Kizel Carboniferous basin, located in a transition zone between the eastern rim of the Russian Platform and the western slope of the Middle Urals. The coal measures of this basin also belong to the productive Lower Carboniferous zone represented by a comparatively monotonous rock sequence repeated several times both vertically and laterally.

Sand and silt units of the coal-bearing sequence consist almost exclusively of rounded quartz grains with accessory minerals represented chiefly by zircon, tourmaline, and rutile. The sandstones are mostly fine-grained, only in places medium-grained. This petrographic and granulometric composition of sandstone suggests a long path and a long duration of transportation and possibly repeated redeposition.

Over 20 coal beds and lentils have been discovered in the basin, most of them located in the middle part of the coal-bearing interval; one or two are of workable thickness.

In structural and geologic features, the basin is divided into three coal-bearing areas, the Chusov, the Kizel, and the Vishera. The most important industrially is the second which has been almost completely explored, at the present time. The coal content of this basin is different in different areas, and is closely related to paleogeographic conditions of the formation of coal measures.

A detailed study of the Kizel coal measures, carried out at different times by I. I. Gorskiy, P. V. Vasil'yev, N. S. Gorodetskaya, G. Ya. Zhitomirov, and a number of other students, has confirmed the existence of a deltaic environment of deposition and formation of coal measures. However, opinion is divided as to the concrete conditions for existence of the delta itself and the genesis of its coal-bearing deposits. A critical evaluation of different views, based on field data for the subaerial delta where the river splits into numerous branches and channels, leads to the establishment of three principal zones, contemporaneous but differing in sedimentation conditions.

1. A zone of relatively stable island marshes and peat bogs. These deltaic islands, oriented latitudinally and persisting for some time, were areas of maximum coal accumulation.

2. An unstable zone of flowing water (a river channel, its branches and tributaries) whose mobile medium precluded almost completely any possibility of coal accumulation;

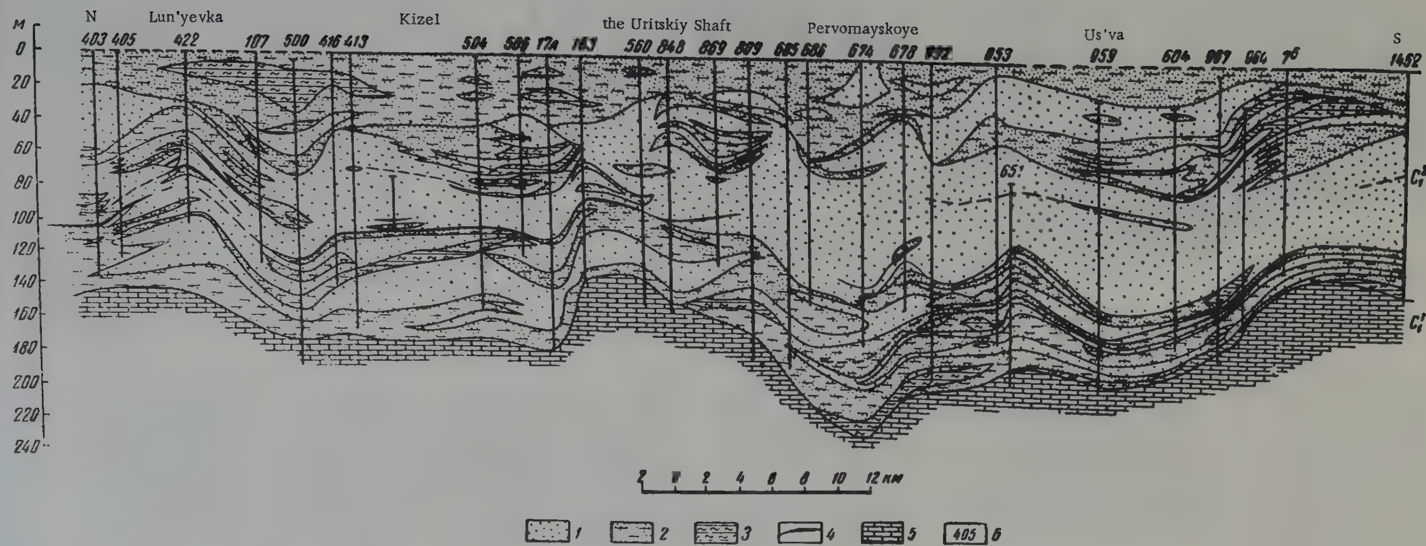

FIGURE 1. Meridional section of the C_1^{2h} coal-bearing sequence in the central part of the Kizel basin. (By N.I. Markovskiy from data of N.G. Sazhin).

1) Sandstone; 2) siltstone; 3) shale; 4) coal; 5) limestone; 6) borehole number.

mostly sand was deposited here, instead.

3. A mixed zone, characterized by a rapid change in environment. In such zones, the islands and the river banks might be flooded or cut through by temporary branches and wandering channels, then become marshy and undergo some other change. Coal beds of such a zone are usually high in ash, thin, commonly wedging out or being genetically replaced by carbonaceous clay.

These zones, all belonging to a discrete deltaic facies, were anything but consistent; on the contrary, they alternated both laterally and vertically. Only rarely do they display the persistence of the same sedimentary conditions. On the whole, their distribution, consistency, and recurrence depended on the rapidly changing conditions of aggradation and downcutting of river waters. In one place, island and offshore shoals were washed out while they came into existence in another.

All that resulted in an extremely motley picture of lithologic varieties shifting about in the terrigenous section. This is well illustrated by a north-south cross-section of the Kizel region (Figure 1). The top of a unit corresponding to the base of the Tula limestone was taken for the datum, thereby eliminating all subsequent influences and restoring, to a certain extent, the situation prevailing prior to the deposition of terrigenous sediments.

The facies environment was relatively stable and enduring in the period of formation of the principal workable beds of the basin (11th and 13th); it is correlative approximately with the beginning of the Yasnaya Polyana age. Noticeable in this interval is a definite regularity in the distribution of coal-bearing and barren areas, corresponding to that of former island and channel zones. On a map, this distribution is represented by that of main workable beds and barren deposits. This is demonstrated by bed 11 (see Figure 2), with consideration given to a partial erosion of coal, connected with the erosion of Hercinian folds and at times hardly discernible from the erosion of ancient peat fields.

Present besides typically deltaic facies, in the beginning of the formation of the Kizel basin terrigenous sequence, are facies connected with a gradually receding sea, expressed in marine and continental deposits. Similar facies are developed in the topmost beds of this sequence, except that here they are transgressive.

Now, if there is no doubt among students of the Kizel basin as to its belonging to a fairly large delta system, where is the river which carried in and deposited this over 250-m thick body of terrigenous material?

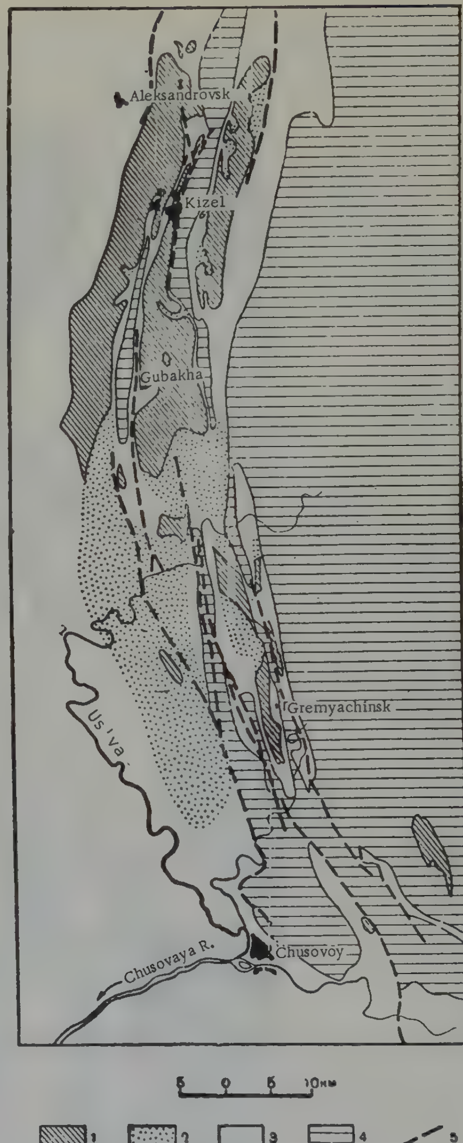

FIGURE 2. Distribution of coal bed 11 in the Kizel basin (After N. G. Sazhin).

1 - coal bed 11; 2 - barren areas; 3 - deposits younger than C_1^{2h}; 4 - deposits older than C_1^{2h}; 5 - fault traces.

We have not found a definite answer to that question in works on this basin. There are several views on the subject. D. V. Nalivkin [4], P. V. Vasil'yev [1], and others believe that an ancient river which fed the delta flowed from a Siberian continent, i. e., from east to west. This would imply the presence of a Visean landmass at the site of the Uralian geosyncline and west Siberian synclise; and of a marine basin in the east part of the Russian Platform. Such assumptions are in direct contradiction to most

recent field data.

First of all, no Stalinogorsk marine sediments have been found on the platform west of the Kizel area. On the contrary, they acquire there a definitely continental character. Sandstones which account for 40 to 90% of the entire thickness of the coal-bearing section, in the Kizel area, are monomineral, consisting of well-rounded and well-sorted quartz grains. Present to a small extent among minerals of the heavy fraction are zircon, tourmaline, and rutile. Unstable minerals are almost totally lacking in both fractions. Granulometrically, sandstones are represented chiefly by fine-grained varieties (0.1 to 0.25 mm) typical of alluvial-deltaic deposits that have been transported over long distances by plains-land rivers.

The coal-bearing section of the Kizel basin, studied in many boreholes and mines, is characterized by a very inconsistent distribution of individual lithologic facies, both vertically and laterally. This, too, suggests their deltaic channel origin.

The eastern continuation of the ancient delta is truncated by recent erosion. Nevertheless, in areas of Druzhinino, Lys'va, and Kuzino villages, in the southeast part of the basin, areno-argillaceous rocks change gradually to marine carbonate facies. The effect of a marine environment is also apparent in the Skal'ninsk area where sideritic sandstone is not only widely developed but carries marine algae remains, as well. Still farther south, in the area of Kyn and Obmanka villages, intercalations of limestone and dolomite appear in the coal measures.

Thus, if the sea was located east and southeast of the Kizel delta, clastic material undoubtedly should have come from a land lying in the opposite direction. However, probably the most convincing argument against an easterly source for the terrigenous material is provided by the results of a study of petrographic and textural features of this sequence, particularly its cross-bedding. The latter has long been noted by many students but for some reason never used as evidence in reconstructing the paleogeographic conditions of formation of the coal-bearing sequence.

In 1955, a paper by G. A. Smirnov and I. S. Svirshchevskiy [5] was published on a special study of cross-bedding in the Kizel area. This subject is dealt with also in a later paper of G. A. Smirnov [6], in considering the sedimentation conditions during the Uralian Visean. In recent years, coal exploration geologists have started a systematic study of cross-bedding in coal measures.

Bodies of mixed-grained, cross-bedded sandstone, locally up to several meters thick, have been observed in various localities of the basin where they occur mostly in the middle and intermediate beds. Cross-bedding is expressed here in parallel laminae whose primary dips attain 20 or 30°, locally as much as 40°. The cross-bedded units usually are underlain and overlain, with sharp angular unconformity, by more regularly bedded sandstones. This type of cross-bedding, typical of deltaic deposits, is most common in the Kizel basin. Less common is another type where regular stratification at the base of a bed gradually changes upward to cross-bedding. The contact with overlying beds, too, is expressed by a sharp angular unconformity.

Determinations of the primary orientation of dips in cross-bedding, for sandstone of the coal-bearing sequence, from mines and outcrops, show a remarkable consistency. Most primary cross-bedding dips (70% of over 120 points) were east-northeast and east-southeast. The remaining cross-beds dip north-northwest and only at isolated points to the northwest, according to G. A. Smirnov [6].

The most recent measurements of cross-bedding in shafts in the Kospash-Poludennaya syncline as well as from deep levels in the Stalin and the Uritskiy shafts indicate that here, too, the primary cross-bed dips are either to the northeast or east. At no place have westerly dipping cross-bedding been observed.

G. A. Smirnov notes the following regularity in the distribution and character of cross-bedding in the Kizel area. In the center of the area, near Gubakha village, cross-stratified beds are rather thin and have fairly steep cross-bedding consistently oriented east-northeast. In the Us'va Valley to the south, the cross-bedded sandstones are not as thick and the cross-bedding is considerably flatter. Moreover, the direction of dip of cross-bedding is not as consistent as in central areas of the basin.

Thus the cross-bedding in sandstones of the Kizel terrigenous sequence, undoubtedly of deltaic origin and an azimuthal in orientation, is direct evidence of a river flowing from the Russian Platform rather than from a Siberian continent as previously assumed. The mouth of this ancient river was located west of the Gubakha-Gremyachinsk line, with its channel in a latitudinal trough between the Verkhnekamsk arch to the north and the Krasnokamsk-Polaznen swell to the south. Consequently, clastic material came chiefly from the west and northwest where the main source of sediments lay in the Baltic shield area. This is corroborated also by the petrographic composition of a sandstone-siltstone sequence, almost completely monomineral, while material coming from east and southeast and deposited within the eastern slope of the South Urals, is markedly polymictic.

The problem of the source of sediments is

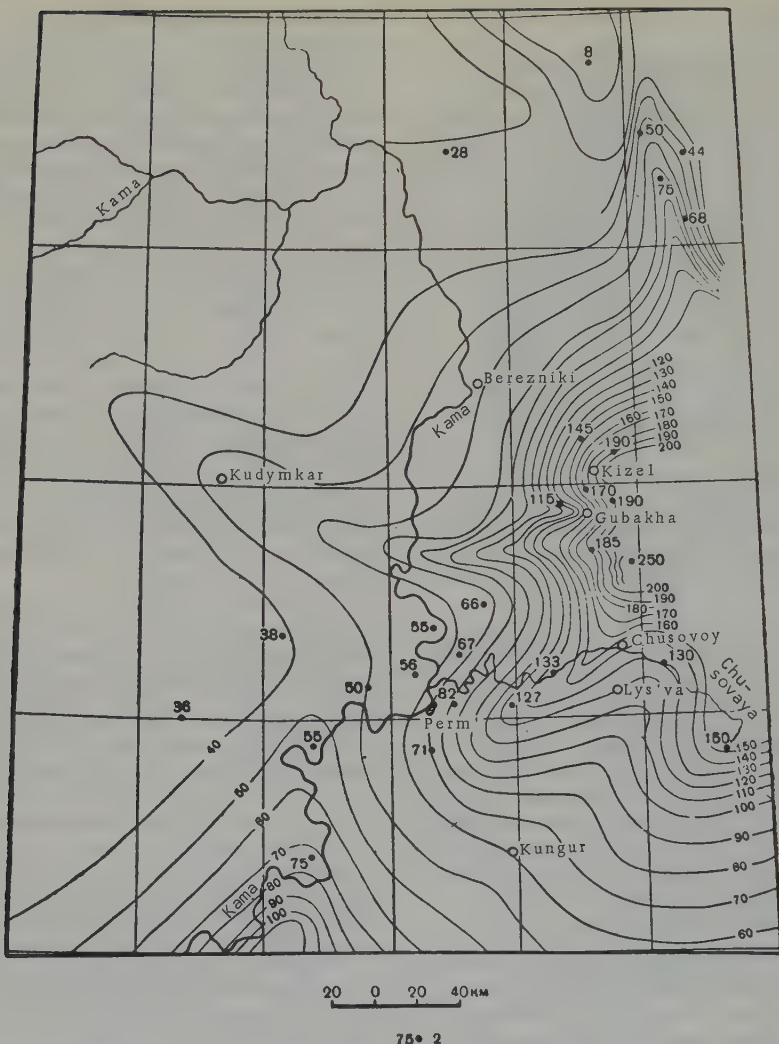

FIGURE 3. Isopach map for the terrigenous Lower Carboniferous of the northeast part of the Perm Urals.

particularly important, both theoretically and practically. It sheds a new light on the genetic aspect of the Kizel basin and on oil and gas prospects in the areas to the west.

Where the subaerial part of the delta witnessed the development of peat bogs which subsequently gave rise to coal beds, the adjacent vast shallow-water zone was a site of mass accumulation of plant and animal organic matter which became the source of oil and gas. The topographically higher position of deltaic and alluvial-channel deposits, in relation to oil source rocks, promoted a migration of oil and gas toward the Russian Platform, during the consolidation of these sediments, and an oil and gas accumulation in terrigenous Lower Carboniferous reservoirs. Such reservoirs were represented chiefly by valley alluvium.

During the Hercynian orogeny, a portion of the subaerial delta as well as the delta front were involved in the folding of the west Uralian slope. The estuarine segment of the ancient river remained on the platform. Thus the oil source rocks and reservoirs were again at different topographic levels, under conditions still favorable for a further formation of oil and gas fields.

Although the Perm Uralian region, west of the Kizel basin, still is very little explored by drilling, the data at hand, with some extrapolation, are adequate for making an isopach

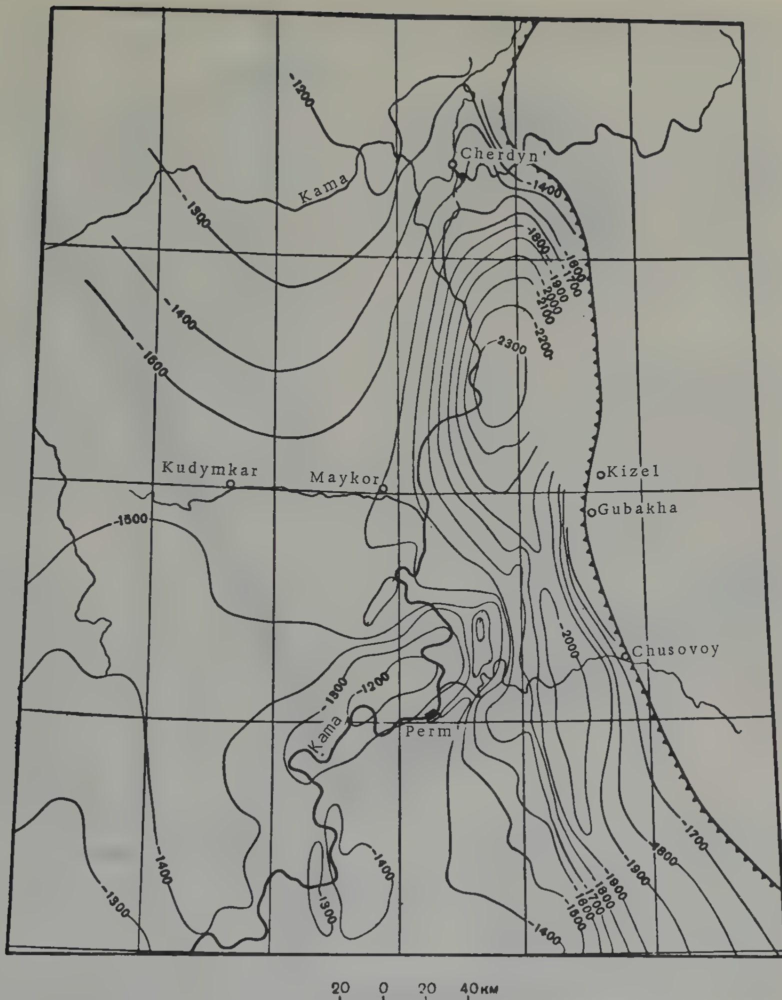

FIGURE 4. Structural map of the northeast part of the Perm Urals. Contours on top of the Tula sequence (C_1^{2tul}) (After K. S. Shershnev).

map (Figure 3) extending beyond the drilled areas. This map indicates the nature of the change in thickness of the terrigenous sequence and reflects to some extent the ancient relief prior to its formation. Considering the configuration of the isopachs and the paleogeographic conditions in adjacent areas in the east part of the Russian platform, the main direction of the ancient river valley, at least in its lower course, can be assumed to have been nearly latitudinal. Its middle course apparently cut the Kudykmar area, with its upper course still farther to the northwest.

The isopach pattern in the area of Chusovaya River suggests the presence of another branch or of a river flowing from the southwest. The presence of a river valley in the north part of the basin as suggested by the isopach pattern in the Vishera coal area, cannot be ruled out. These possibilities must be checked by surveying, geophysics, and drilling. It should be noted in this connection that the presence of several estuaries at a short distance from each other does not contradict the general pattern of their distribution along a sea coast where they may be either lacking or else almost continuous.

The present structure of the eastern rim of the Russian Platform is in fair agreement with the isopach map. A structural map, drawn on the Tula unit (Figure 4), suggests that the

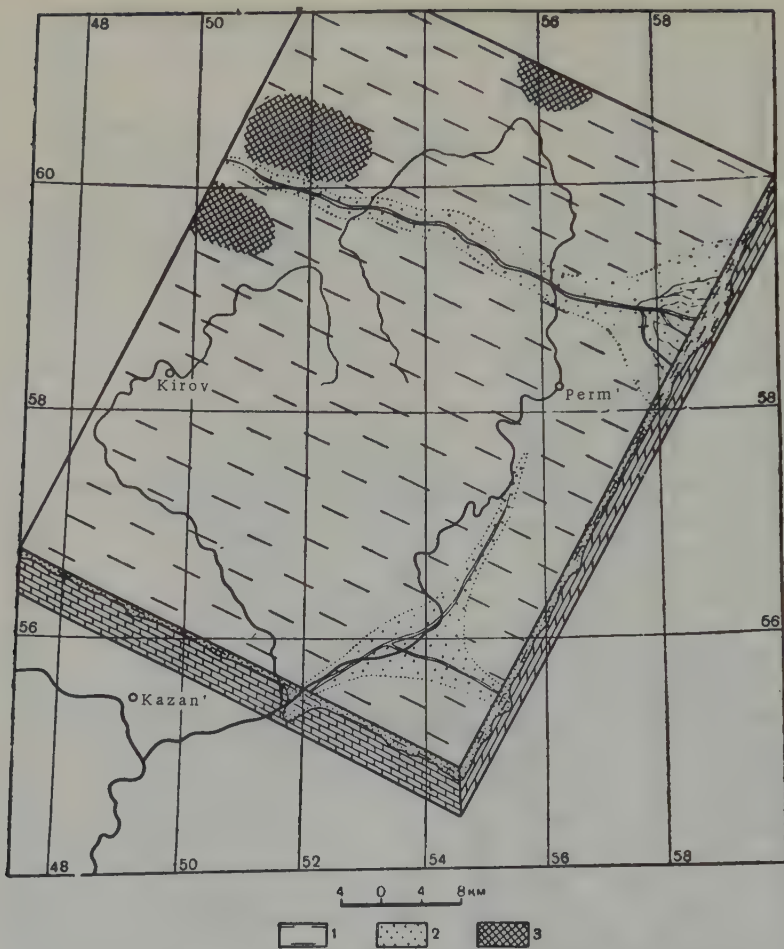

FIGURE 5. Generalized paleogeographic map of the Perm Ural region at the beginning of the Visean.

1 - marsh-lacustrine plain; 2 - river valleys; 3 - areas of higher relief.

general tectonic features of a Early Paleozoic platform were inherited to a certain extent by the present structure. The map shows that the western part of this area appears to be divided into two elevated segments corresponding to the Verkhnekamensk arch and the Vyatka uplift zone. Separating them is a saddle which may be called the Kudykmar; it is a natural trough which offered a path of least resistance for a river channel. This assumption is corroborated by a thickness increase in the terrigenous sequence, from Polazna to the Yarino oil exploration area, 18 to 20 km from there. Sandstones thicken in the same direction, attaining 34 m in the Yarino well No. 1 and 52 m in well No. 2. The reservoir properties of the sandstone also improve in that direction. This is another proof that the deepest central segment of a river valley is located north of the known oil area of the Permskaya Oblast'.

It is quite obvious that a determination of the true position of this ancient valley, and especially its estuary, is important in evaluating coal, oil, and gas prospects of the Upper Kama region. It is true that west of the Kizel basin the coal measures plunge to a depth of over 2000 m, in their passage across the Uralian foredeep. Even still farther west, in their rise to the eastern rim of the Russian Platform, they do not come up higher than 1200 to 140 m below the surface.

However, while great depths are a negative feature in the search for new coal areas, the same factor is positive in the preservation of the oil field.

A great variety in elevations is present also on the southeastern slope of the Russian Platform, along the lower and middle Volga, where

the plain changes to the Caspian depression.

A reconstruction of the physical environment for the formation of the productive Lower Carboniferous sequence is not complete without a paleogeographic description, the general outline of which, on the basis of facies analysis, is as follows. A vast humid plain, covered by numerous marshes and bodies of water, supported a widely developed hydrographic network divided into individual, more or less large, river systems. This network, most important in the formation of a terrigenous sequence, depended on ancient relief, tectonic conditions, and especially climate. The climate, to judge from fossil flora, was warm and humid, with abundant tropical downpours radically affecting the hydrodynamic status of the rivers as well as flooding the marshes and peat bogs. Thus, precipitation affected to a considerable extent the speed and the nature of deposition of terrigenous material.

A paleogeographic block diagram in Figure 5 does not purport to represent the one-time hydrogeographic network which is practically unreconstructible. At the most, only the valleys of the most important ancient rivers are detectable in their fossil state. Such a valley of the river flowing Kizel Bay or else directly into a Middle Urals Early Carboniferous sea is suggested in the north of this area. The headwaters of a previously discovered ancient river [2], extending along the middle and lower course of the present Kama, then along the Volga, and into a marine basin located in the Caspian depression, are fairly well outlined in the southeast.

The diagram also shows areas of thinning in the terrigenous sequence which is marked there by an even more continental aspect, suggesting thier relatively high position in the ancient relief. They include the Ksenofontovo area and northeastern parts of the Kirovskaya Oblast'.

The most important paleogeographic feature is the estuarine delta part of this ancient river. First, its subaerial portion with a long-established commercial coal content may extend to the west, with the scope of such an extension determined by technically practicable and profitable production depth. Secondly, deltaic and alluvial channel deposits, especially those above the Uralian foredeep, may be gas bearing. This is ever so much more probable because extremely rich oil pools have been discovered in the Kinel'-Cherkassy area of the Kuybyshev Trans-Volga region, in the delta of the other ancient river of the same Early Carboniferous age previously mentioned.

We already have pointed out [3] the simultaneous formation of Lower Carboniferous coal measures and oil source beds in adjacent provinces or zones of a Volga-Ural sedimentary basin. The spatial change from land to sea, from one facies and geochemical environment to another, together with the frequent gas and oil showing encountered in the Kizel basin shafts, are an even more convincing proof of regular spatial relationship between regional processes of coal accumulation and oil formation. They both were most closely related to a definite stage of the intensive development of plant and animal organic matter and to those favorable conditions of concentration which are most frequent in the littoral zone of eternal struggle between land and sea.

The present attempt at refining the position of the Kizel basin in the general paleogeographic scheme of the eastern extremity of the Russian Platform at the onset of the Tournaisian is based on the most recent data obtained from drilling for coal and especially for oil, in areas of the Perm Ural and the Volga regions. It is quite obvious that these data are still inadequate for a detailed reconstruction of the boundaries and relief of an ancient continent which this area was at the time. However, this paleogeographic interpretation of the Kizel region and adjacent areas presents a new approach to their coal, oil, and gas prospects and to more rational planning for further exploration of these fossil fuels.

REFERENCES

1. Vasil'yev, P. V., Paleogeograficheskiye usloviya formirovaniya uglenosnykh otlozheniy nizhnego karbona zapadnogo sklona Urala. [PALEOGEOGRAPHIC CONDITIONS DURING THE FORMATION OF LOWER CARBONIFEROUS COAL MEASURES ON THE WESTERN SLOPE OF THE URALS]. Ugletekhizdat, 1950.

2. Markovskiy, N. I., O paleogeografii nizhnevizeyskogo vremeni v rayonakh Srednego Povolzh'ya i Zavolzh'ya. [EARLY VISEAN PALEOGEOGRAPHY IN AREAS OF THE MIDDLE AND TRANS-VOLGA REGIONS]. Dokl. AN SSSR, t. 104, No. 4, 1955.

3. Markovskiy, N. I., Ugol' i neft' v Volgo-Ural'skoy oblasti. [COAL AND OIL IN THE VOLGA-URAL PROVINCE]. Priroda, No. 5, 1957.

4. Nalivkin, D. V., Geologicheskaya istoriya Urala [GEOLOGIC HISTORY OF THE URALS]. Sverdgiz, 1943.

5. Smirnov, G. A. and Svirshchevskiy, I. S., Paleogeograficheskoye znacheniye kosoy sloistosti peschanikov uglenosnoy tolshchi v Kizelovskom rayone na Urale. [PALEOGEOGRAPHIC SIGNIFICANCE OF CROSS-BEDDING IN SANDSTONES FROM COAL MEASURES IN THE KIZEL

AREA, THE URALS]. Dokl. AN SSSR, t. 100, No. 6, 1955.

6. Smirnov, G. A., Materialy k paleogeografii Urala (vizeyskiy yarus). [PALEOGEOGRAPHIC DATA ON THE URALS (VISEAN STAGE)]. Tr. Gorno. -Geol. Inst. Ural'sk. Fil. AN SSSR, vyp. 29, 1957.

All-Union Scientific Research Institute
Panki Settlement,
the Moskovskaya Oblast'.

Received June 10, 1058

EVOLUTION OF QUATERNARY VOLCANISM IN THE SREDINNYY (MIDDLE) RANGE OF KAMCHATKA[1]

by

E. N. Erlikh

In connection with exploratory work in the Sredinnyy Range of Kamchatka and with the discovery here of recent mineralization related to secondary quartzite, the problems of Quaternary volcanism, of criteria differentiating younger extrusives, of the age of the mineralization, and of its relation to volcanic activity, become ever more important.

Up to recently, these problems have attracted but little attention.

The first draft of a general outline of Quaternary volcanism in the Sredinnyy Range was attempted by K. I. Bogdanovich [14]. He believed that the oldest extrusives were represented by basic hypersthene-augite andesite related to crater-like summits of Hoa-Shen (Ichinsk volcano), Anauna, Aynelkan, Shishel, and others. He believed extrusive acid andesite and dacite of the Belyy Range, Hangar, and Hoa-Shen represented a second stage; and finally, augite andesite of the most recent extrusives represented the third stage. According to K. I. Bogdanovich, major fault-surface outpourings of feldspathic basalt in the Tigil and Sreddinnyy Range are associated with the second stage. It also was assumed that the volcanoes were associated with isolated peripheral igneous centers, independent of tectonics.

This classification gained considerable importance; up to the middle 1940's, all students either adhered to it (A. V. Shcherbakov, D. S. Kharkevich) or avoided criticism of it (B. F. D'yakov). Later on, in studying individual volcanoes (T. Yu. Marenina) and in regional surveying (Yu. V. Zhegalov, Yu. V. Makarov, A. F. Marchenko, and others), stages of volcanic effusions were determined in individual working areas, without a specific frame of reference. Problems of regularities in distribution of the Kamchatka volcanoes were considered by A. N. Zavaritskiy [5] who assumed a relationship between volcanic centers and deep faults and outlined the main directions of such faults.

[1]Ob evolyutsii chetvertichnogo vulkanizma v zone Sredinnogo khrebta Kamchatki.

The specific geochemical features of the Sredinnyy Range lavas have not yet been studied.

For the last five years, as a result of study by the Far Eastern and the Fifth Geological Administrations, the knowledge of Quaternary volcanism in the Sredinnyy Range has increased considerably, and it is now becoming possible to undertake the task of determining general regularities in the evolution of volcanic processes, the spatial distribution of volcanic apparatus, and some features of the geochemistry of lavas.

First, let us consider criteria for classifying Quaternary extrusives. That can be accomplished only by a comprehensive use of a number of features. The petrography of such rocks is very diversified, and known examples of lavas covering Quaternary deposits are comparatively rare. Because of these facts, comparison of different volcanic formations by geomorphic features assumes great importance because the same type of volcanic activity implies a similarity in the structure of the extruding mechanism, while a similarity in the lava composition and in the timing of flows (under the same tectonic conditions, of course) predetermines a similar erosional effect. It is very important to clarify the relationship of lavas representing different extrusive stages with glacial processes. The latter problem has usually been outside the scope of interest of the students of the Sredinnyy Range; therefore, there is not much known on that subject. A. F. Marchenko alone studied in detail the petrography of morainal boulder material and the relationship of different types of moraines over a large area; as a result, he has arrived at some very interesting conclusions. Finally, a major criterion is the history of the largest volcanic structures, inasmuch as they reflect features typical of volcanism throughout the entire zone.

Thus, the following factors must be taken into consideration in classifying Quaternary extrusives: 1) the petrographic and chemical composition of a lava; 2) characteristic forms of extruding apparatus; 3) the comparative

history of major volcanic structures; 4) relationship between lavas of different stages and volcanic processes; 5) relationship of lavas from different stages and volcanic processes; 6) geomorphic features.

Modern methods should be widely used, such as absolute-age determination, differentiation by residual magnetism in lavas, and spore-pollen analysis of unconsolidated deposits marking some parts of a Quaternary complex. Unfortunately, none of these methods is used to any extent.

We shall turn now to direct exposition of our material.

Plateaus formed by flows of basic extrusives are widely distributed throughout the Sredinnyy Range. They also form the northern part of the Kozyrev Range and extend to Moroshka Pass, west of Sredinnyy Range, forming the crest of Pankovan Range and individual summits in the west and south parts of the area. The lavas were extruded here on an ancient peneplain formed at the close of the Pliocene. The contact of extrusive flows with that peneplain can be observed in a number of exposures.

The plateau-building extrusive section is fairly uniform over considerable distances; it is as follows:

1. Locally present at the base are conglomerate lenses of Tertiary extrusives with a friable cement commonly carrying an addition of tuffaceous material. Thickness, 25 m.

2. They are overlain, as a rule, by dipyroxene andesite and andesite-basalt with brecciated tuff lenses in their lower part. Total thickness, 150 to 200 m.

3. The section is culminated by dense gray olivine basalt with coarse (0.2 to 0.4 cm) incrustations of olivine. The rocks exhibit a typical, fine slaty parting. This is consistent everywhere and may serve as a good marker. Average thickness, 200 to 250 m.

The over-all thickness of this section range from 200 to 400 m, because andesite and breccia are missing in some areas, probably these areas most distant from the source.

The rocks are horizontal everywhere; dips of 3 to 8° have been observed only in the lower part of the section, probably reflecting ancient buried relief.

Judging from the wide areal distribution of these flows, their horizontal position, the extremely small amount of pyroclastic material, and the general predominance of basalts, the outpourings were something like a mass-fracture flow. Traces of the extruding apparatus are present in gently sloping ridges, with elevations of 1300 to 1400 m above sea level. They are formed by scoria and agglomeratic material of the same composition as andesite and basalt of the plateaus, with isolated layers of olivine basalt.

Such ridges are present in three principal zones: 1) the Kozyrev Range; 2) the Sredinny Range; and 3) west of Khayryuzovka River, between Icha River in the south and the Bol'shoy Payalpan and Yang-Yang Mountain in the north.

All zones are parallel to each other, with a common north-northeast trend, and are associated with regions of linear uplifts of Tertiary basement, which began to form between the Late Pliocene and the Quaternary and are fixed at the present time by the absolute elevations of the top of Quaternary sediments. The flows were apparently connected with fractures in the apex parts of these uplifts. The abundance of scoria and agglomeratic material along the fractures indicates that the eruptions were accompanied by powerful explosions. The flow occurred on land; however, we have observed a spherical parting in andesite at the base of the section, which suggests a submarine initial stage. The extrusives filled up all hollows in the relief and formed a plateau system with an elevation of 1100 to 1200 m above sea level. Judging from the generally lower elevations, to the west-northwest (from 1200 m at the foot of the Kozyrev Range 700 to 800 m west of the Pankovan Range and 600 m on the Kulkev-Okat River) and from the considerable thinning in the same direction (from 400 to 500 m in the Kozyrev Range down to 150 m south of Chingeyngeyn Mountain and 10 to 30 m at the Moroshka Pass), sources of the largest outpourings were in the northeastern part of the zone (the Kozyrev Range, and Sredinnyy Range along the middle course of Bystraya). In the Kozyrev Range, these extrusive plateaus are broken up by faults with throws of 300 to 600 m and occur at elevations of 1600 to 1800 m above sea level.

On the whole, this complex is similar in all features to the "plateau extrusives" of A. Heik and T. Bart [1].

The stratigraphic position of plateau extrusives is determined by the fact that they rest on a peneplaned surface of dislocated Tertiary deposits, the youngest of which are Upper Miocene or Pliocene. At the same time, the plateau everywhere shows evidence of ancient glaciation expressed in a series of deep gorges which cut its western part; in the main trough of the Bystraya and Khayryuzovka valleys; and in the deposition of morainic material on the plateau surface. That glaciation was a semi-blanket. We correlate it with the maximum east Siberian glaciation (according

o V. N. Saks) which corresponds to the Riss or Dnieprovian glaciation in Europe and, according o S. A. Yakovlev, is Middle Tertiary in age.

Considering that the Tertiary-Quaternary age boundary for Kamchatka is tentative, the age of the entire complex should be assumed to be Pliocene to Early Quaternary. This age range is corroborated by data, on the absolute value of residual magnetism in lava, obtained by the author as a result of paleomagnetic analysis of specimens collected him. The average value of coefficient $Q(I_n/I_i)$ for plateau basalt (olivine basalt) is 1.85, which is close to an earlier value of 1.33 obtained by N. Ye. Kalinnikov for the Mil'kovo area plateau basalt. According to A. G. Komarov (All-Union Geological Institute — VSEGEI) these values suggest a Pliocene - Early Quaternary age for these rocks (extrusives of the Kavransk Pliocene formation have an even lower value: Q = 1.15).

This complex of plateau extrusives has been identified by A. F. Marchenko for the northern part of the Sredinnyy Range; by M. F. Dvali, Yu. V. Zhegalov, Yu. V. Makarov, L. I. Tikhomirov, and E. N. Erlich, for its central part; and according to V. P. Mokrousov, it occurs in small remnants as far as the Kolpakova River basin. Plateaus similar in genesis, morphology, and age, but with an andesite composition, are widely distributed in eastern and southern Kamchatka [8, 9]. The wide areal extent, the consistency in thickness, the similar origin and tectonic character, and the definite age range of this complex make it possible to designate it as a stratigraphic unit — the "plateau extrusive formation."

From the second atage on, and during a long period, the extrusives are not of a fissure nature but are rather more or less localized about individual eruptive centers. Of especial importance are, therefore, a study and correlation of the history of major volcanic structures of this zone, which have passed through similar stages of development. The following general sequence of major volcanic structures is suggested:

Stage one is the formation of a polygenetic volcano, similar to a shield type, whose lavas are marked by an andesite-basalt to basalt composition. Such are the base of the Khangar Sopka; an ancient crater of the Ichinsk volcano; and volcanoes Ketepana, Malaya Ketepana, Bol'shoy and Malyy Chekchebonay, Ochchamo, Uksichan, Yanga-Yagay, and a volcano I discovered in the Bystraya-Khayryuzovka watershed and named "the Leningradets," etc.

The section in all these structures is as follows. Present at the base are brecciated tuffs with intercalations of acid andesite and some obsidian. They change upward to andesite-basalt, tholeiite basalt, quartz basalt (the latter observed specifically in the Uksichan volcano section). In areas of the Uksichan, Ichinsk, and Ochchamo volcanoes, lavas of this complex are seen to rest on olivine basalt which mark the top of the plateau extrusive formation.

The stratigraphic position of such structures is determined by the fact that eruptions of all those volcanoes occurred after the first glacial epoch, as demonstrated by the flow of the Ochchamo lavas through an ancient canyon of Oyemtevlan river, of the Bongabti lavas through the Dimshikan canyon, and Uksichan lavas through the canyons of Annar and Migiveyem rivers. At the same time, all structures which we have assigned to this complex show evidence of a younger glaciation related to the second stage of a mountain-valley type glaciation. Such are small gorges and canyons on the west slope of Uksichan Mountain; the Anmanna Valley trough which cuts lavas of the "Leningradets" volcano; the Yanga-Yagay River which cuts across a volcano of the same name; and canyons associated with Ketepana and Malyy Ketepana volcanoes. All these canyons begin in cirques at their upper reaches, do not extend over long distances, and terminate at elevations not lower than 600 m above sea level.

In the character of glaciation and in relationship to Quaternary marine transgression, we correlate the second glacial epoch in Kamchatka with the Zyryanian glaciations recognized by V. N. Saks [11] for eastern Siberia. It corresponds to the Würm of Europe, which is Quaternary.

Thus we date the entire system of volcanoes as Middle Quaternary.

According to A. G. Gamarov, the average value of coefficient Q of the residual magnetism for lavas from shield-like volcanoes of the Sredinnyy Range is 3.5. The same values were obtained from Japanese interglacial basalts. An interglacial origin for such volcanoes is suggested also by A. F. Marchenko who has found out that boulders of their lavas are missing in moraine of the first glacial epoch but form most of the second epoch moraine. It cannot be discounted, however, that the localization of individual eruptive hearths of the central type began simulataneously with fissure flows, in areas of a lower intensity in movement.

Stage two is characterized by cauldron development related to explosions of the Katmay type (volcanoes Khangar, Aynelkan, "Leningradets," and Ochchamo). In a number of volcanoes (Uksichan, Yanga-Yagay) circular subsidence cauldrons were formed as a result of the evacuation of the magmatic chamber, which had taken place during the

preceeding stage. Such cauldrons took in a large part of the volcano, with small remnants of the shield volcano lavas persisting along their outer rim. Simultaneously, acid extrusions were emplaced in the center and along the periphery of a cauldron Uksichan, Khangar volcanoes, etc.), during the growth of a stratavolcano (Ichinsk volcano) accompanied by explosive activity, as witness the presence of volcanic breccia in almost all types of such structures. The petrographic composition of these extrusive bodies was marked by an abundance of biotite andesite and andesite-dacite. Liparitoid varieties of dacite are comparatively rare. The young crater of the Ichinsk volcano is marked by the so-called "Hoa-Shen' type andesite" (after K. I. Bogdanovich) alternating with sizable layers of brecciated tuff of the same composition.

This stage began at the very end of the second glacial epoch and terminated as recently as post-glacial time. Chingeyngeyn and Bol'shoy and Malyy Payalpans mountains, despite their considerable height, (about 2000 m) far above the present snow line, bear no traces of glacial scouring. In the upper courses of Anmanna and Degdanna rivers, acid tuffs are located in glacial cirques of the second glacial epoch. On the other hand, T. Yu. Marenina notes that eruptions of the main Khangar cone began as early as the glacial epoch and only the explosion which led to the cauldron formation took place in post-glacial time. Both A. F. Marchenko and Yu. V. Zhegalov assign the acid extrusions to the end of the second glacial epoch.

For all these reasons, we assign a Recent age to all of the above-named formations.

Thus, during the three stages, along with a contraction of the volcanic hearth area, the lava composition was changing in an acid direction. All this makes it possible to assume a single volcanic cycle within the Sredinnyy Range zone, from fissure flows of olivine basalt through acid extrusions and explosive activity.

It appears from the previously cited general characteristics of the sections that each of the first two stages of the cycle witnessed a change from more acid to more basic varieties of lava. It implies that each stage was preceded by the magma fusing the roof of its hearth and assimilating sedimentary material. As a result, the initial phases of both stages were expressed in flows of andesite whose appearance at that period is difficult to explain by differentiation from a single basalt magma.

With all that unity in the process of evolution within the zone, major differences in the composition of lavas and in the character of eruption within individual centers have led to considerable variety in the types of volcanic structures. The following forms may be noted as peculiar to volcanoes of the first extrusive type:

1) shield volcanoes of the cauldron-free type, e. g., Bol'shoy Chekchebonay, Ketepana, and Malaya Ketepana;

2) shield volcanoes with cauldrons: Malyy Chekchebonay and "Leningradets;"

3) volcanoes having craters of the Vesuvius type: Ichinsk volcano;

4) cone-like stratovolcano: Snezhnaya Mountain;

5) volcanoes with an extrusion in the center of the cauldron: Khangar-Alney;

6) extrusive domes of a regional type: Bol'shoy and Malyy Payalpan and the Levinson-Lessing volcanic extrusion.

In each of these there is a progressive in genesis, depending on the volcano's position within the zone. This relationship is best expressed in the westernmost line of volcanoes.

There, basalt breccias lie at the base of the most southern of these volcanoes, the Khangar, whose main cone is formed by dacite and dacite breccia, capped by a large explosion cauldron. An old crater of the Ichinsk volcano, somewhat to the north, is made up of andesite-basalt with obsidian layers, while its younger crater is andesitic (of the Vesuvius type), with an immense explosion cauldron housing the top cone. The "Leningradets" volcano, still farther north, has lava of a mixed andesite-basalt to basalt composition; the second stage of its activity was marked by the formation of a single explosion cauldron without any trace of lava flows. Ketepana, at the north end of the line, is a shield volcano of a cauldron-free type with peripheral extrusions of acid andesite and dacite.

Thus, going north, each volcano along this line exhibits a weakening of explosive activity and a corresponding general increase in the basicity of lava, more and more approaching pure tholeiite basalt, in average composition.

Unfortunately, the geochemical data on "Leningradets" and Ketepana volcanoes are very scanty. At the same time, a study of the lava composition for the Khangar and the Ichinsk group of volcanoes reveals a strong oversaturation in aluminum in the first, while the second exhibits an excess of aluminum only in varieties close to liparite. As already noted, there is an abundance of dacite from the Khangar and a relative predominance of andesite from volcanoes of the Ichinsk group. Unfortunately, the latter phenomenon has not been

udied from analyses of an appropriate number f silicate samples from different types of lava idividual volcanoes. These peculiarities are ccounted for if we remember that the Khangar vas are underlain directly by granite which is arked by this very excess of aluminum and an oundance of silica. To the north, "the ancient equences" dip under Tertiary sedimentary vol-anic deposits. Parallel to that, the basicity of vas increases up to practically pure tholeiite asalt of the Ketepana. This appears to suggest decrease in the contamination of lava, to the orth, with the plunge of the anticlinorium axis; iis is corroborated by a smaller value for the kalie-lime index of the Ichinsk volcano lavas 54.9) as compared with the Khangar Sopka 58.2).

As regards regularities in the spatial dis-ribution of the first cycle volcanoes, the map 1 Figure 1 shows their localization along the xes of folded structures. For example, there s a western line of volcanoes along the axis f an ancient anticlinorium of the Sredinnyy ange having a near-meridional trend.

The southernmost of these volcanoes, the hangar, is located at the beginning of the nticlinorial splunge, where it is complicated y a number of block subsidences. Somewhat o the north, a group of extrusions occur in the rea of the Levinson-Lessing volcano. They are ocated at the junction of an ancient anticlinorium nd a large Tertiary anticlinal structure trend-ng northeast. The area in which a sharp undu-ationof the ancient anticlinorial axis occurs, here Mesozoic and pre-Mesozoic rocks are ompletely overlain by the Tertiary, contains he largest of the Sredinnaya zone volcanoes, he Ichinsk, with its adjacent smaller structures Cherpuk volcanoes, extrusions of Bol'shaya nd Malaya Payaplans, etc.). Still farther orth there are two other large volcanoes, the Leningradets" at the intersection of faults rending in several directions, and the Ketepana. lo common fault along which all these volcanoes re located has been observed. Each of them is onnected with its individual hearth, the result f local tectonics within a regionally weakened ectonic zone represented by the plunging axis f an ancient anticlinorium.

The second trend controlling the distribution f volcanoes parallels the axis of a northeasterly riented anticlinal structure formed in the Aleu-ian and Tatarian phases of folding. Located long that trend are three groups of volcanoes vith a common feeding hearth for each group. Vithin each group, the volcanoes occur along ault lines associated with the axial part of the tructure. The southern group consists of evinson-Lessing, Ochchamo, and Bongbati olcanoes. The two other groups lie to the orth. The first of the two includes Aynelkan, hishel, and Severnyy volcanoes. The second omprises the Alney, Khuvkhoytun, and "Ostryy" volcanoes. Standing out by itself is the large Alney volcano associated with a steep plunge of the Tertiary anticlinal structure.

The third trend is expressed by a chain of volcanoes, running northwest and connected, according to A. N. Zavaritskiy, with the Aleutian arc which adjoins Kamchatka in the north. Here belong Uksichan, Chingeyngeyn, Yanga-Yagay, and "Leningradets" volcanoes all associated with a fault trending in the same direction.

The fourth trend is represented by a group of volcanoes along the axis of a synclinal fold in Upper Tertiary sediments. It runs N 60° W ("Leningradets," Malaya Ketepana, Bol'-shoy and Malyy Chekchebanay).

Thus, the volcanoes are connected with independent hearths confined, as an effect of local factors, to major structural elements. This view is close to B. I. Piyp's conclusions on regularities in the distribution of the Kluch-evskaya group volcanoes; it also reconciles to a considerable extent the view of A. N. Zavaritskiy and K. I. Bogdanovich.

As we turn now to the problem of the age of hydrothermal activity connected with the first volcanic cycle, we must note the follow-ing facts:

1. Thick zones of secondary quartzite of a definitely interglacial age occur in the north-ern part of the Uksichan volcano. Showings of native gold and cinnabar have been observed in panned concentrates from this zone.

2. A large deposit of metasomatic sulfur minerals is associated with the crater of the Alney volcano, of the same age.

3. L. I. Tikhomirov notes that in the Polovinnaya River sulfur deposit, the lower part of Lower Quaternary plateau extrusives carries traces of hydrothermal alteration.

4. Within Lower Quaternary plateau extru-sives on one of the left tributaries of Tigil' River (near Chavych River), a large zone of secondary quartzite was noted in panned con-centrates, with cinnabar observed near it.

5. A zone of secondary quartzite is located in the cauldron of the Quaternary Ochchamo volcano.

6. Not a single boulder of secondary quart-zite has been observed in high fluvioglacial terraces of Bystraya and Khayryuzovka rivers, while they are present to a considerable extent in lower alluvial terraces.

All this facts suggest that hydrothermal activity which determined the formation of

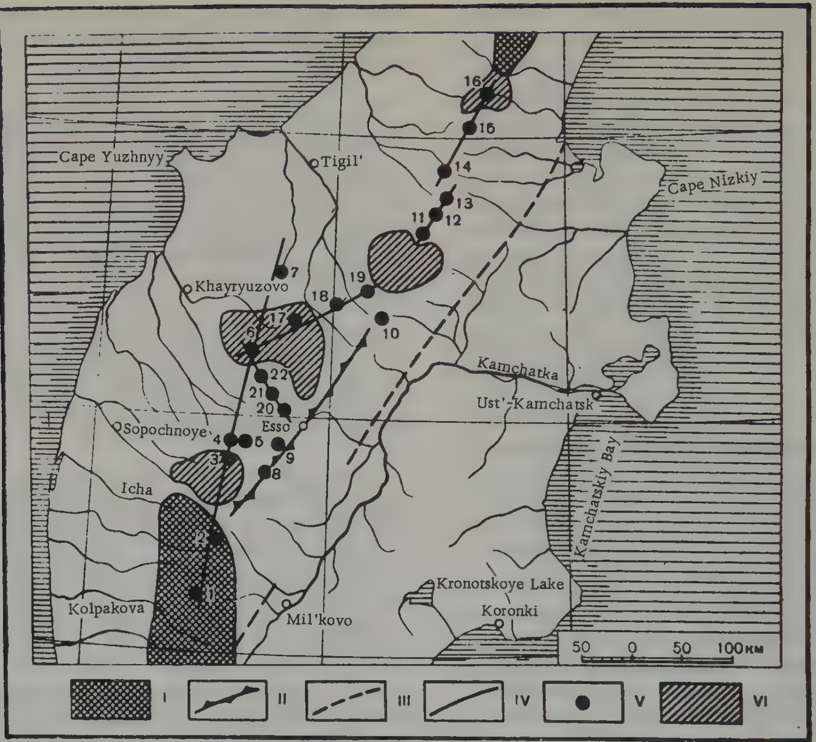

FIGURE 1. Diagrammatic map of volcanoes of the Sredinnyy Range zone, Kamchatka.

I - Mesozoic and pre-Mesozoic rocks; II - axis of Tertiary anticlinal structure; III - fault limiting the Kamchatka river depression in the west; IV - trends of volcanoes; V - volcanoes of cycle one; VI - centers of most recent volcanism (figures on map); 1 - Khangar; 2 - a group of extrusions in the area of the Levinson-Lessing volcano; 3 - Ichinsk; 4 - Bol'shoy Payalpan; 5 - Malyy Payalpan; 6 - "Leningradets;" 7 - Bol'shoy Ketepana; 8 - Ochchamo; 9 - Bongabti; 10 - Alney; 11 - "Bezymyannyy," el. 2024 m above sea level; 12 - Shishel'; 13 - Aynel'kan; 14 - Aleny; 15 - Khuvkhoytin; 16 - "Ostryy;" 17 - Malaya Ketepana; 18 - Bol'shoy Chekchebonay; 19 - Malyy Chekchebonay; 20 - Uksichan; 21 - Chingeyngeyn; 22 - Yanga-Yagay.

zones of secondary quartzite and of ore showings is connected with Quaternary volcanism, more precisely with its third stage marked by explosive activity and acid intrusions. The age of all these formations is assumed to be that of the end of the second glaciation and the beginning of the post-glacial epoch.

The most recent volcanism within the Sredinnyy Range should be considered separately. Until very recently, it has been assumed that its scale was extremely small. According to most students, the eruptions of that time were chiefly explosive, with nearly all products of eruption concentrated in a scoria cone, without a vent. All volcanoes were regarded as extinct; P. T. Novograblenov alone hinted vaguely at a possible fumarole activity in the Ichinsk volcanic area [10].

The results of our own work, along with data of previous investigators and a study of aerial photographs of the central and northern parts of the Sredinnyy Range, make it possible to revise radically former concepts on this subject.

In the Tigil'-Bystraya (Khayryuzovka) watershed, we have observed a large number of small volcanoes which were the source of large sheet flows. These flows were of a fracture character in tectonically active areas; a large (60 km in diameter) volcanic knob north of Chaba River has been described; it represents a large shield volcano known as "Geologists' Knob." The eruption sequence in this area can be represented, somewhat diagrammatically, as follows: 1) massive flows of olivine basalt; 2) powerful explosive discharges connected with numerous scoria

ones; 3) emplacing of extrusive bodies of an-esite, andesite-dacite, and dacite.

All of the volcanic formations in this region re practically unaffected by erosion, with lava ows covering glacial and fluvio-glacial deposits long Tikhaya, Anmanna, and Degdanna rivers, nd penetrating the valleys of modern rivers.

The second center of recent volcanism is in ne Ichinsk volcanic area. Here, the general equence of eruptions is similar to that described bove. Present along with Severnyy and Yuznyy herpuk, "Palets," "Dva Brata," and other olcanoes whose lavas are represented by oli-ine basalt, there are extrusions of acid lavas n the north slope of the volcano; according to . I. Vlodavets's summary [4], they are pre-ent also on its south side.

Judging from data of A. F. Marchenko and u. V. Zhegalov, and from aerial photographs, nother large center of recent volcanism may xist north of the Alney volcano (Cherpuk, eutongey, Kebensey, Baydara, and many other olcanoes).

Thus recent time witnessed another and uite independent cycle, repeating on the whole ne course of the first cycle, from olivine ba-alt to acid extrusives.

A distinctive feature of this new cycle is its apid rate of progress compared with the first ne, as well as a direct transition from sheet nd Hawaiian type flows (instead of fracture ows of the first cycle) to explosive activity nd the final phase of acid extrusives. These eatures appear to be connected with a more asic composition of lava in this cycle, most robably similar to olivine basalt.

A manifestation of terminal stages of this ycle can be observed in fumaroles of the chinsk volcano, discovered in 1956 [13], and n numerous thermal springs widely developed long faults within that zone (Kireunskiy, zernovskiy, Apapel'skiy, Oksinskiy, Essov-kiy, Anavgayskiy springs, etc.).

As shown on the map (Figure 1), the most ecent volcanic hearths are associated with harp plunges of folded structures and with najor regional faults. In the areas of such earths, the manifestations of recent volcanism re scattered. The eruptions are connected with umerous individual volcanoes aligned along ractures trending mostly N 60° W, with some solated meridional and latitudinal trends. The istance between lines of volcanoes is 3 to 5 m. This appears to suggest shallower channels irectly feeding these volcanoes, as compared vith the first cycle volcanoes where that dis-ance is 25 to 30 km. (in accordance with the aw of L. Green and D. Friedlander functionally onnecting the distance between volcanoes and the depth of their direct-feeding magmatic center).

For an understanding of geochemical features of Quaternary volcanic processes within this zone, the author has compiled a summary of chemical analyses of the extrusives (Table 1), from publications [2, 3, 6, 7, 12] and from his own data. An attempt was also made to correlate the age of lavas sampled and the stages of volcanism (from personal observations and from aerial photographs). All analyses were recomputed by the A. N. Zavaritskiy method (Table 2) and the results presented in a diagram of chemical composition of lavas (Figure 2).

An analysis of this diagram and comparison of variation curves of cycles one and two with that for Quaternary extrusives of eastern Kamchatka, given by B. I. Piyp [8], reveals the following typical geochemical features of Quaternary extrusives from the Sredinnyy Range zone:

1. An excess of calcareous aluminosilicate, generally typical of the Kamchatka extrusives, is even greater here.

2. A general oversaturation in aluminum is present especially in acid rocks.

3. The main distinctive feature of this zone is a general increase in alkalicity in the Sredinnyy Range lava as compared with similar rocks of eastern Kamchatka. The degree of alkalicity grows toward the west coast where tephrites appear along with normal olivine basalt in the Tigil' River basin (according to A. V. Aksenovich). The comparative abundance of dacite and other alkalie-rich rocks evidently is a typical feature of Quaternary volcanism in the western zone as it is true generally for the interior of island arcs. All these features are intensified in lavas of the second cycle as compared with the first cycle extrusives.

Variation diagrams for $Na_2O + K_2O - CaO$ (Figure 3) show a somewhat higher value for the alkalie-lime index for the second cycle, thus suggesting a higher degree of contamination in the original magma and corroborating the presence of somewhat shallower feeder hearths of this cycle compared with those of the first cycle extrusives.

Such are the basic regularities in the development of Quaternary volcanism in the Kamchatka Sredinnyy Range.

It is expedient to correlate the Sredinnyy Range volcanism with Quaternary volcanism in southern and eastern Kamchatka. Even now there are many facts suggesting contemporaneous and geologically similar volcanic processes, corresponding to the outlined stages,

Table 1

Chemical composition of Quaternary extrusives in the Sredinnyy Range, Kamchatka

Speci-men Nos	Sample locality	Age	Components					
			SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO
1	Dike at Orlov volcano	Q_1	50.78	0.69	15.53	3.84	5.10	0,20
2	Plateau in northern part of Sredinnyy Range	»	47.48	1.30	18.47	6.53	3.84	—
3	Plateau in the Bystraya River valley	»	49.94	0.94	14.46	7.68	4.50	0.19
4	" " " " "	»	45.96	0.62	15.16	7.73	4.97	0.17
5	Levinson-Lessing volcano	Q_2	57.00	0.53	17.32	1.38	5.88	0.22
6	Ochchamo volcano	»	52.62	0.92	18.58	4.25	4.55	0.17
7	" "	»	52.13	0.77	18.20	4.04	4.85	0.07
8	Ketepana "	»	52.69	0.60	20.06	5.27	3.21	0.09
9	Bol'shoy Payalpan Mountain	Q_3	56.07	1.74	17.09	2.59	4.70	0.20
10	" "	»	59.78	0.97	15.81	1.15	5.73	0.15
11	Ichinsk volcano	»	54.90	—	20.23	3.42	5.26	0.18
12	Khangar "	»	65.95	0.62	16.12	4.32	0.00	0.11
13	"	»	66.65	0.48	15.41	1.94	1.49	0.10
14	"	»	69.17	0.41	17.60	1.70	1.40	0.06
15	"	»	58.48	0.49	17.10	1.60	1.54	0.09
16	"	»	63.80	0.80	18.39	4.50	0.00	0.12
17	"	»	67.44	0.54	16.15	2.25	0.84	0.10
18	"	»	72.42	0.23	15.04	0.42	0.88	0.09
19	"	»	74.04	0.26	14.03	0.64	0.84	0.08
20	"	»	74.04	0.26	14.08	0.64	0.84	0.08
21	Upper course of Bystraya River	»	71.82	0.41	13.56	0.85	1.17	0.09
22	Chingeyngeyn volcano	»	53.27	0.84	19.41	3.00	5.35	0.15
23	Acid tuffs of "Leningradets" volcano	Q_3	63.85	0.44	18.37	3.38	0.65	0.16
24	Extrusion at Malaya Ketepana	»	55.61	0.70	20.23	2.12	3.48	0.06
25	Upper course of Bystraya River	»	74.56	0.28	13.84	0.46	0.81	0.10
26	Kabalan Mountain	»	66.12	0.37	16.00	5.10	0.14	0.13
27	Ichinsk Volcano	»	64.82	—	18.53	3.38	0.12	Traces
28	" "	Q_4	46.82	—	20.52	6.10	5.14	Traces
29	Tekovayam River	»	46.99	1.20	18.10	3.69	6.27	0,10
30	" "	»	47.00	1.04	18.49	5.44	6.34	0.10
31	Anaun volcano	»	52.68	—	18.25	6.61	3.39	0.16
32	" "	»	55.61	0.70	20.23	2.12	3.48	0.06
33	" "	»	55.58	0.70	18.66	5.20	4.90	0.06
34	" "	»	48.24	0.76	18.01	3.70	7.77	0.15
35	Tikhaya River	»	52.43	1.80	11.03	8.71	5.60	0.23
36	Orlov volcano	»	51.42	0.68	15.51	4.12	4.82	0.16
37	Kynynnok volcano	»	73.05	0.06	15.83	0.48	0.36	0.02
38	Yurtochnyy "	»	63.56	0.59	17.42	4.19	—	0.08
39	Ichinsk "	»	65.71	0.66	15.61	1.57	2.50	0.09
40	Area of South Cherpuk	»	66.86	0.50	12.80	4.89	1.72	0.06
41	" " "	»	68.98	0.42	12.75	1.44	1.39	0.11
42	" " "	»	70.56	0.41	14.30	1.27	1.72	0.03
43	" " "	»	72.98	0.17	14.01	1.72	1.01	0.09
44	Ichinsk volcano	»	51.24	1.28	15.89	7.76	2.76	0.14
45	" "	»	63.64	0.63	15.59	2.98	2.52	0.07

Table 1

continued

Components										
MgO	CaO	BaO	Na_2O	K_2O	P_2O_5	H_2O	Losses in heatings	S	Cl	Total
8.39	11.48		2.01	0.87	0.57	0.08	0.47	—	—	100.11
8.41	10.50	—	3.43	0.26	0.09	0.29	—	0.03	—	100.63
8.48	9.00	—	2.48	1.33	0.37	0.07	0.21	—	—	99.68
8.67	10.86	—	1.40	3.40	0.68	0.45	0.38	—	—	100.47
5.42	7.27	—	3.09	1.51	—	—	0.72	—	—	99.85
5.50	8.90	—	2.60	1.25	0.22	0.13	0.60	—	—	100.19
5.51	8.85	—	2.85	1.70	0.18	0.03	0.63	—	—	99.78
4.91	7.65	—	5,23		—	—	0.57	0.08	—	100.56
2.68	5.23	—	4.30	2.45	1.23	0.20	0.85	—	—	99.35
3.10	4.69	—	3.45	1.35	0.19	0.24	3.78	—	—	100.49
3.11	6.24	—	4.86	1.44	—	—	0.54	—	—	100.18
0.13	3.61	—	3.89	3.45	0.29	0.28	0.40	—	—	100.17
0.97	3.32	—	3.99	3.10	0.22	0.19	1.94	—	—	99.80
0.98	2.04	0,04	3.10	2.76	—	0.89	0.11	—	—	100.26
1.02	2.30	0,06	4.5	2,78	—	0.15	0.16	—	—	100.27
1.52	4.52	—	3.71	2.63	—	0.09	0.11	—	—	100.19
1.35	3.31	—	3.38	2.63	Traces	1.83	0.21	—	—	100.03
0.54	1.52	—	4.15	4.18	None	0.05	0.15	—	—	99.67
0.29	1.03	—	4.08	4.06	Traces	—	—	—	—	99.35
0.29	1.03	—	4.06	4,08	Traces	0.06	0.57	—	—	100.03
0.43	1.55	—	3.45	3,65	0.079	0.12	2.53	—	—	99.80
4.33	8.05	—	3.46	1.30	—	0.20	1.09	0.30	—	100.31
0.90	4.30	—	5.08	2.53	0.19	0.10	0.10	—	—	100.50
3.89	7.29	—	4.16	1.71	—	0.30	0.33	0.33	—	99.61
0.39	1.55	—	3.85	3.72	0.08	—	0.27	—	—	99.91
1.34	4.11	—	3.41	2.12	0.20	0.14	0.53	0.04	—	99.75
1.35	4.10	—	3.71	2.81	—	—	1.18	—	—	100.00
6.20	8.90	—	4.45	1.69	—	—	0.16	—	—	99.98
8.31	10.20	—	4,36		—	—	0.54	0.10	—	99.68
5.84	10.13	—	5,28		—	—	0.00	0.22	—	99.72
4.72	9.58	—	3.24	0.69	—	—	0.24	—	—	99.74
3.89	7.29	—	4.16	1.74	—	0.30	0.33	0,33	—	99.61
5.06	8.86	—	3.00	0.87	—	0.12	0.30	0.30	—	99.49
7.15	10.13	—	2,80	1,12	—	0.07	Incr. in Weight	0.23	—	99.85
6.15	8.19	—	2.92	1.44	0.43	0.45	0.93	—	—	100.31
8.24	10.88	—	1.98	0.92	0.20	0.52	0.73	—	—	100.18
0.28	1.63	0,12	5.18	2.77	0.06	0.08	0.32	—	—	100.24
2.10	4.43	0,13	5.08	1.91	0.38	0.08	0.36	—	—	100.31
1.49	3.75	—	3.55	2.90	0.11	0.06	2.00	—	—	99.91
1.74	3.54	—	3.31	2,71	—	1,04	0.28	0.03	0.03	99.51
2.85	1.26	—	4.98	4.77	—	0.19	0.17	0.06	99.45	0.09
1.13	1.20	—	3.87	4.24	—	0.65	None	None	90.05	99.43
0.50	0.60	—	4.42	3.98	—	0.68	0.02	0.03	0.02	100.23
6.72	8.06	—	3.35	2.52	—	0.46	0.12	0.05	0.10	100.46
1.85	4,48	—	3.87	3.03	—	0.57	0.25	Traces	0.07	99.55

Table 2

Chemical analysis of Quaternary extrusives from the Sredinnyy Range, recomputed by the A. N. Zavaritskiy method.

Analyses Nos.	Parameters								
	a	c	b	s	a′	f′	m′	c′	n
1	5.7	8.4	28.8	57.1	—	28.8	49.1	21.9	77.1
2	8.0	8.7	27.3	56.0	—	30.9	53.1	16.1	54.6
3	7.0	6.0	30.0	57.0	—	36.4	47.6	16.0	76
4	8.1	6.1	33.0	52.8	—	34.0	44.5	21.5	39
5	8.7	6.8	21.6	62.9	—	31.10	40.85	28.05	75.57
6	8.1	9.2	20.2	62.5	—	49.89	47.77	11.34	75.68
7	8.9	7.9	22.3	60.9	—	43.62	42.37	10.91	71.88
9	13.5	5.3	13.3	67.9	—	53.5	35.8	10.7	72.7
10	10.0	6.0	12.3	51.7	1.15	54.59	44.25	—	72.28
11	13.3	7.5	14.2	65.0	—	58.5	38.5	3.0	83.95
12	13.8	4.0	6.1	76.1	—	62.0	31.0	7.0	63.0
13	13.6	3.6	5.3	77.5	—	59.0	33.0	8.0	66.0
14	10.4	2.4	11.8	75.4	62.0	23.0	15.0	—	63.0
15	13.6	2.7	7.7	76.0	43.0	36.0	21.0	—	71.0
16	12.3	5.6	7.1	75.0	24.0	56.0	20.0	—	68.0
17	11.1	3.9	7.1	77.9	30.0	39.0	31.0	—	66.0
18	13.5	1.8	4.9	79.7	50.0	31.0	19.0	—	66.0
19	14.3	1.2	3.0	81.5	42.22	42.22	15.55	—	60.09
20	14.4	1.2	3.3	81.1	36.0	48.0	16.0	—	60.0
21	13.7	1.3	5.0	80.0	48.0	37.33	16.47	—	59.04
22	9.9	8.7	17.6	63.8	—	45.0	46.0	9.0	80.0
23	12.1	8.0	13.5	66.4	—	40.0	51.0	9.0	78.4
24	15.0	4.9	5.6	74.5	—	65.4	27.2	7.4	75.1
25	13.3	1.8	2.7	82.2	31.7	43.9	24.4	—	61.4
26	10.7	5.0	7.9	76.4	—	59.1	28.7	12.1	71.4
27	12.4	5.0	7.9	74.7	31.7	37.7	29.8	—	66.6
28	12.7	7.9	24.4	55.0	—	42.25	44.25	13.5	90.0
30	8.2	8.2	22.9	60.7	—	49.2	35.3	15.4	93.6
32	12.1	12.1	13.2	66.6	—	40.0	51.0	9.0	80.0
33	8.1	8.5	22.1	61.3	—	41.0	42.0	17.0	82.0
34	8.0	8.3	27.4	56.3	—	40.0	46.0	14.0	80.0
35	8.5	3.1	29.6	58.8	—	42.7	34.6	22.6	75.4
36	5.7	7.6	27.8	58.9	—	29.6	50.0	2.3	75.9
37	14.9	1.9	22.9	83.0	61.4	25.0	12.6	—	73.9
38	13.9	4.8	7.9	74.4	—	46.1	45.2	8.7	80.03
39	12.2	5.8	4.5	78.5	—	58.51	39.36	2.13	64.77
40	11.2	2.9	10.0	75.9	—	57.0	30.0	13.0	65.0
41	16.3	c—0.8	7.8	75.1	—	23.0	59.0	18.0	61.0
42	14.3	1.4	5.9	78.4	25.0	44.0	31.0	—	60.0
43	15.1	0.9	5.2	79.3	33.0	51.0	16.0	—	63.0
44	11.0	5.0	25.3	58.7	—	38.0	47.0	15.0	65.0
45	13.0	4.0	9.7	73.33	—	50.0	35.0	15.0	66.0

Note: Analyses 1, 36, 37, and 38 after A.A. Menyaylov and S.I. Naboko [7]; 11, 27, and 28 after K.I. Bogdanovich [14]; 12, 13, and 20 after A.V. Shcherbakov (1937); 14-19 after T. Yu. Marenina [6]; 2 after A.F. Marchenko; 25 and 26 after V.I. Vlodavets [3]; 3 after D.S. Kharkevich [12]; 40 and 45 after V.I. Vlodavets [4]; 24-10, 21-24, 29-35 and 39 from original data of the author. Computed by the author.

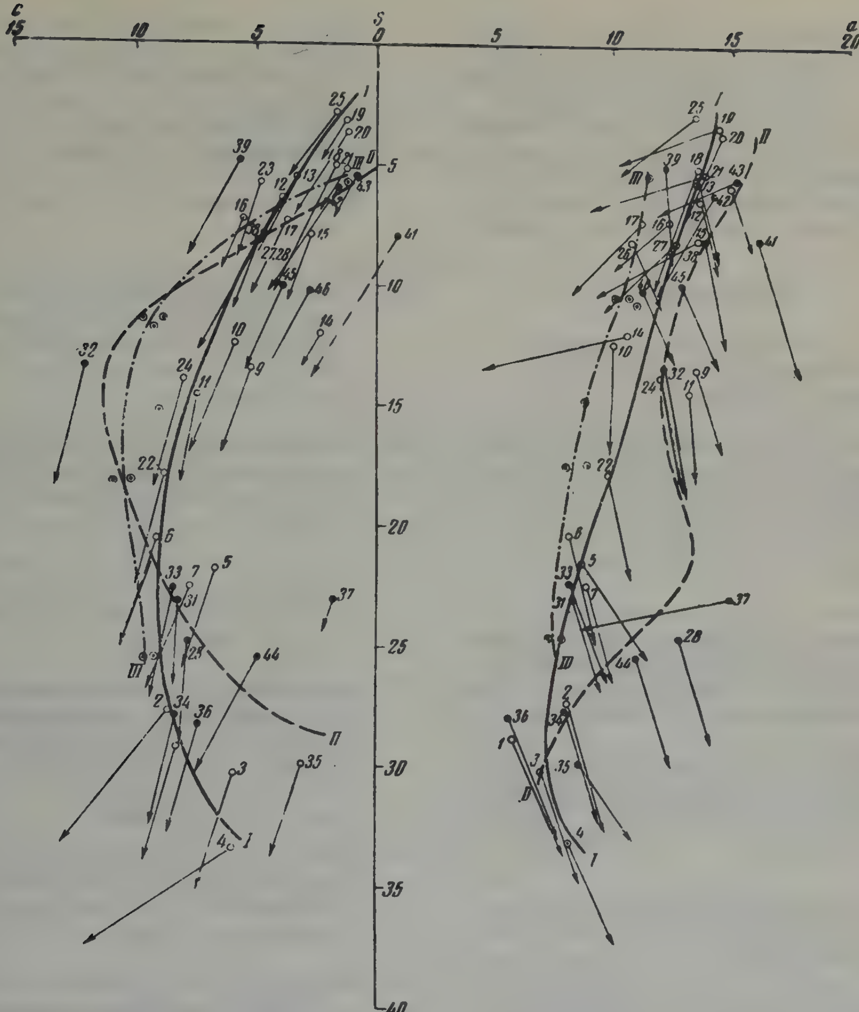

FIGURE 2. Diagram of chemical composition of Quaternary extrusives from the Sredinnyy Range, Kamchatka.

Variation curves for the composition of lavas: I - Cycle One; II - Cycle Two; III - Quaternary extrusives in eastern Kamchatka (after B. I. Piyp, [8]). Parameters in analyses of Cycle I, hollow circles; Cycle II, black circles; eastern Kamchatka extrusives, circles with a dot inside.

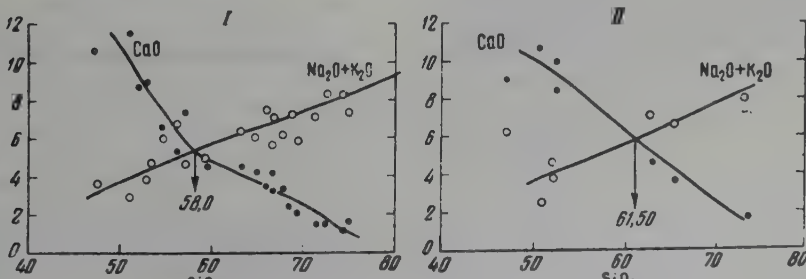

FIGURE 3. Variation diagram CaO - (Na_2O + K_2O) for Cycle One (I) and Cycle Two (II) of Quaternary extrusive activity in the Sredinnyy Range.

throughout the peninsula. The single nature and the contemporaneous occurrence of plateau basalt flows throughout Kamchatka has been noted previously. Many students have emphasized the similarity in the history of major volcanoes of western and eastern Kamchatka. The difference appears to be in the intensity of individual volcanic stages for different zones, while their nature and the time of flow are the same.

REFERENCES

1. Bart, T., Teoreticheskaya petrologiya [THEORETICAL PETROLOGY] Izd. Inostr. Lit., 1956.

2. Vlodavets, V.I., O khimicheskom sostave Kamchatskoy magmaticheskoy provintsii. [CHEMICAL COMPOSITION OF THE KAMCHATKA IGNEOUS PROVINCE]. In Sb. Vopr. Mineralogii, Geokhimii i Petrogr. Izd. AN SSSR, 1946.

3. Vlodavets, V.I., Khimicheskiy oblik izverzhennykh porod Kamchatki. [CHEMICAL ASPECT OF EXTRUSIVE ROCK IN KAMCHATKA]. Byull. Vulkanol. Stantsii na Kamchatke, No. 5, 1939.

4. Vlodavets, V.I., Katalog deystvuyushchikh vulkanov Kamchatki. [CATALOGUE OF ACTIVE VOLCANOES IN KAMCHATKA]. Byull. Vulkanol. Stantsii na Kamchatke, No. 25, 1957.

5. Zavaritskiy, A.N., Vulkany Kamchatki. [VOLCANOES OF KAMCHATKA]. Izd. AN SSSR, 1955.

6. Marenina, T. Yu., Istoriya obrazovaniya i izverzheniy vulkana Khangar. [HISTORY OF THE FORMATION AND ERUPTIONS OF THE KHANGAR VOLCANO]. Avtoref. Kand. Diss., LGU, 1952.

7. Menyaylov, A. A. and S.I. Naboko, Potukhshiye vulkany Verkhne-Yelovskogo rayona na Kamchatke. [EXTINCT VOLCANOES IN THE VERKHNE-YELOVSK REGION OF KAMCHATKA]. Tr. Kamchatk. Vulkanol. Stantsii, vyp. 2, 1948.

8. Piyp, B.I., Materialy po geologii i petrografii rayona rek Avachi, Rassoshiny, Gavanki i Nalachevy na Kamchatke. [DATA ON GEOLOGY AND PETROGRAPHY OF THE AREA OF AVACH, RASSOSHNAYA, GAVANKA, AND NALACHEVA RIVERS IN KAMCHATKA]. Tr. Kamchat. Kompl. Eksp. 1936-1937 gg., vyp. 2, 1941.

9. Piyp, B.I., Klyuchevskaya sopka i yeye izverzheniye v 1944-1945 gg i v proshlom. [KLYUCHEVSKAYA SOPKA AND ITS ERUPTION IN 1944-1945 AND IN THE PAST]. Tr. Labor. Vulkanol., vyp. 11, 1956.

10. Novograblenov, P.T., Katalog vulkanov Kamchatki. [CATALOGUE OF KAMCHATKA VOLCANOES]. Izv. Russk. Geogr. Ob., t. 64., vyp. 1, 1932.

11. Saks, V.N., Chetvertichnyy period v Sovetskoy Arktike. [THE QUATERNARY IN SOVIET ARCTIC]. Glavsevmorput', 1948.

12. Kharkevich, D.S., Izverzhennyye porody Sredinnogo Kamchatskogo khrebta. [EXTRUSIVE ROCKS OF THE KAMCHATKA SREDINNYY RANGE]. Tr. Kamchatsk. Kompl. Eksped. 1936-1937 gg., vyp. 1, 1940.

13. Ehrlich, E.N., Voskhozhdeniye na vulkan Ichinskiy. [ASCENT OF ICHINSK VOLCANO]. Byul. Kamchatsk. Vulkanol. Stantsii, No. 27, 1958.

14. Bogdanovitsch, K., Geologishe Skizze von Kamschatka. Peterm. Geogr. Mitt., Gotha, 1904.

Fifth Geological Administration,
Ministry of Geology and Conservation
of Mineral Wealth of the U. S. S. R.,
Leningrad

Received October 10, 1958

PETROGRAPHIC SKETCH AND GEOCHEMISTRY OF THE SANDYK MOUNTAINS ALKALIC INTRUSION (NORTHERN KIRGHIZIA)[1]

by

B. I. Zlobin

The composition, structure, and conditions of formation of a complex Variscan intrusion in ie Sandyk Mountains are described. Nepheline syenite of a miaskite type, first discovered here, id pseudo-leucite varieties are described. A consideration of the origin of these intrusive rocks om a geologic and geochemical point of view precludes application of the R. Daly hypothesis. The emise of a primary magmatic nature of all rocks in this intrusion and of their possible thermo-ffusive liquational formation is advanced.

* * * * *

The intrusive Variscan igneous activity in orthern Tyan'-Shan' is very little known. The nall intrusions of this cycle, scattered over considerable area, are much inferior to a aledonian granitoid massif of the batholith pe and are often marked by higher alkalicity.

The Sandyk Mountains Variscan alkalic in-usion is among the most alkalic derivatives f late Paleozoic igneous activity in northern yan'-Shan' where its composition is syenitic, eaching nepheline syenite; it is also marked y a well expressed differentiation of component ocks.

This intrusion is located in the eastern part f the Dzhumgol' Range and occupies an area f about 70 km^2. This region lies in the Sus-myr (southern) zone of the Tyan'-Shan' caledo-ids and borders on a province of "the develop-ient of superposed epi-Caledonian structures f the middle Paleozoic," identified by N. M. initsyn as the northern caledonid zone. "A ide zone of Hercinian faults between the orthern and southern caledonids" [11] appar-ntly was what constituted a favorable struc-ural factor in the localization of the Sandyk Iountains intrusion. In K. D. Pomazkov's iew [10], this intrusion is associated with aults within the Sonkul'-Alamedin mobile zone, rending northwest, and belongs to intrusions f Carboniferous or Permian age.

On a map, the Sandyk Mountains syenite in-rusion has the form of an irregular triangle. s morphology is not as yet completely known. It appears to be a laccolithic intrusive body of fracture type and hypabyssal occurrence, dipping north and northeast. The enclosing rocks mostly are Caledonian granitoids of the Susamyr batholith, and to a smaller extent Lower Silurian terrigenous sediments and undifferentiated lower Paleozoic metamorphics (Figure 1). Syenite forms sharp contacts with all these rocks.

Initial information on the composition of these intrusive rocks was obtained by geologic surveying by a party from the Kirghiz Geological Administration, under the direction of K. D. Pomazkov, in 1951 and 1952. During the 1953 - 1956 study, the author was able to supplement and refine the knowledge of the petrography of this complex plutonic body. For example, nepheline syenite of the miaskite type and its pseudo-leucitic varieties were first discovered here, along with a number of minerals hitherto unknown from this area, such as sodalite, hackmanite, melanite, zeolites, thorianite, etc. Peculiarities in the composition and structure of this intrusion, and consideration of them from a geologic and petrochemical point of view precludes application of the R. Daly hypothesis and similar concepts in explaining the origin of syenite rocks of this massif.

A PETROGRAPHIC SKETCH

Alkalic rocks of the Sandyk Mountains were formed in two intrusive phases and are represented by the following principal types, from older to younger, in order of formation:

---

[1] Petrograficheskiy ocherk i petrokhimiya shchelo-hnoy intruzii gor Sandyk (Severnaya Kirgiziya).

		km^2	%
First intrusive phase (early)	a) alkalic gabbroids	8	11.4
	b) alkaline-earth syenite	25	35.7
	c) facies of leucocratic alkaline-earth syenite	22	31.5
Second intrusive phase (late)	d) hornblende alkalic syenite	10.5	15.0
	e) nepheline syenite	4.5	6.4

This sequence of development of the intrusion stands out clearly despite the more or less general coincidence of all derivatives and their genetic relation to a common, original alkalic

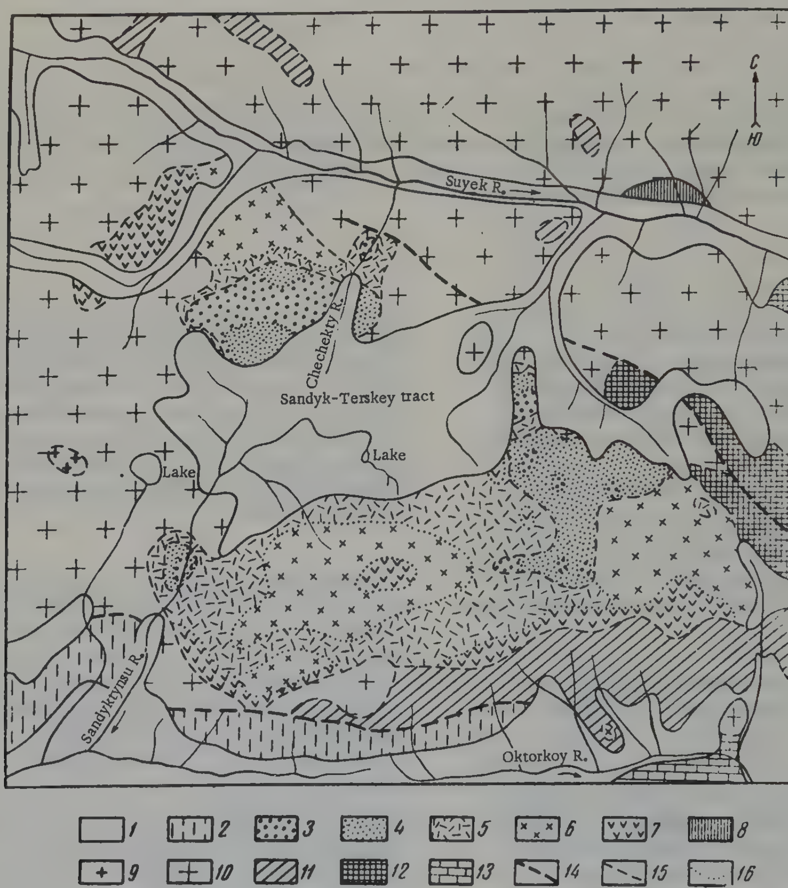

FIGURE 1. Generalized geologic map of the Sandyk Mountains alkalic intrusion; 1958; scale, 1:170,000. (Compiled by the author, with some material on the geologic structure of the intrusion area borrowed from K. D. Pomazkov).

1 - Quaternary; 2 - Tertiary loam, sandy loam, and arkosic sand; 3-4 - alkalic rocks of second phase of Sandyk Mt. intrusion: 3 - nepheline syenite; 4 - hornblende alkalic syenite; 5-8 - alkalic rocks of first phase: 5 - facies of leucocratic syenite; 6 - alkaline-earth syenite; 7 - alkalic gabbroids; 8 - Middle Devonian extrusives; 9-10 - Caledonian granitoids of the Susamyr batholith; 9 - leucocratic granite of third phase; 10 - porphyritic granite and granitoids of second, or the main, phase; 11 - Lower Silurian dark slate, siltstone, and hornfels; 12 - lower Paleozoic crystalline schist, phyllite, and hornfels; 13 - lower Paleozoic marble; 14 - fault traces; 15 - eruptive contacts; 16 - boundaries of intrusive facies.

gma. It is reflected in both the relationship ween the rocks and in their specific composi- n. The intrusive body is zoned. Syenites of first phase form the peripheral and apex ts of the intrusion and are located in areas highest relief. Syenite of the second phase, ally only 21% of the total, usually outcrop places of lower relief where they underlie first phase syenite at the foot of slopes or e in the channel portion of deeply incised leys of the mountain rivers Sandyktinsu and eketa. In isolated places, they crop out on her levels, as well, forming ledges or else umnar-lenticular bodies in overlying syenite the first phase (sic).

Such disturbances in zonation are due to the rusion having been formed in an unstable tec- ic environment, as witness the widely devel- ed trachytoid textures in syenite. These pro- ectonic phenomena are expressed in the par- el planar orientation of flattened feldspars, h a steep dip and a latitudinal (or nearly itudinal) strike. It has been noted that the chytoid structure is least conspicuous in lest rocks, alkalic gabbroid, and in the ngest, nepheline syenite. It appears that initial and the terminal stages of develop- nt of this intrusive body proceeded under re advanced tectonic conditions. However, se movements were very intensive, in a mber of places, during the preceding crys- lization at stage two, judging from the pres- ce of intrusive breccias in which angular enite fragments of phase one, without any ces of recrystallization and fusing, are mented with leucocratic hornblende syenite of ase two.

The relationship of both phases commonly ggests a nearly contemporaneous formation these derivatives. For example, nepheline enite, without any fusing phenomena or any ange in composition is in contact with the erlying alkaline-earth syenite along an un- en but clearly defined surface, with syenite the first phase only slightly cataclastic in contact zone and without any evidences of crystallization and metasomatic alteration. edominant among alkalic rocks of the Sandyk untains intrusion is syenite of the first phase presented chiefly by pyroxene-biotite alkaline- rth varieties. Their different facies exhibit ange in mineral composition with different antitative ratios.

a) Alkalic gabbroids are the most melano- atic representatives of this group. They cupy a small area of the outcrops and are ncentrated chiefly in peripheral and apex rts of the intrusive body. These are medium- ained rocks with 30 to 40% K-Na-feldspar thoclase and anorthoclase with $\beta{:}\perp 001$ = 5 to 8°; 2V = -54°, 61°; 25 to 40% augite- opside (γ = 1.714; α = 1.694; 2V = +56°, 61°; = 43°); 10 to 35% plagioclase (No. 50); and 5 to 15% reddish-brown biotite. Olivine is locally present consisting of about 58% Fo and about 42% Fa. Magnetite and apatite are abundant accessory minerals. Fluctuations in the mineral composition make it possible to separate essentially pyroxene monzonite-shonkinite with not over 5 to 10% plagioclase, and monzonite-essexite with the amount of plagioclase about equal to or slightly exceeding that in K-Na-feldspar. A typical gabbroid representative, specimen No. 1055, is similar in chemical composition to the median essexite type of R. Daly (Table 2 and Figure 4).

b) Alkaline-earth syenites are most common. They are represented by gray coarsely crystalline rocks with K-Na-feldspar incrustations whose orientation is responsible for a trachytoid texture of the rock. They differ from alkalic gabbroids by a higher content of K-Na-feldspar and a lower content of dark minerals. Their typical representatives have the following mineral composition: 60 to 70% iridescent K-Na-feldspar (orthoclase with $\beta{:}\perp 001$ = 6 to 10° and 2V = -58°, -88°); 10 to 15% light-gray pyroxene of the diopside-augite series (γ = 1.716; α = 1.688; 2V = +60°; $c\gamma$ = 38 to 41°); 15 to 20% intermediate plagioclase No. 40, 50, and 5 to 10% dense, coarse-scaled reddish-brown biotite. The more melanocratic varieties of syenite approach monzonite, with olivine occasionally appearing in them, while the more leucocratic varieties contain an addition of quartz. Magnetite and apatite with occasional sphene and zircon are typical accessory minerals.

The most typical representative of this facies is compositionally similar to alkaline-earth (and mica) syenites of R. Daly and to monzonite (see specimen 265 in Table 1 and 2 and Figure 4).

c) The facies of leucocratic alkaline-earth syenite is very closely related to the preceding one, both spatially and in its material composition. Figure 1 shows the leucocratic facies frequently surrounding the outcrops of alkaline-earth syenite, separating them from rocks of the second phase. In alkaline-earth syenite, they may form vein-like or lenticular bodies without any evidence of eruptive interaction. On the whole, the zone of development of leucocratic syenite is represented by rapidly alternating alkaline-earth syenite and leucocratic syenite, with the latter predominant; also by various intermediate varieties. The composition of these syenites is similar to the alkaline-earth types, differing from them in an even larger content of iridescent K-Na-feldspar (up to 70 or 80%) and a lower content of dark minerals (total of 10 to 15%). Epimagmatic light-green hornblende is commonly developed here on pyroxene, with quartz present in the amount of 2 to 5%, and accessory magnetite, sphene, apatite, zircon, pyrite,

Table 1

Quantitative mineral composition of some typical alkalic rocks from the Sandyk Mountain intrusion (in weight %)[1]

Minerals	rocks of the first phase				
	Specimen 271; monzonite-essexite	Specimen 1174; monzonite-like alkaline-earth syenite	Specimen 1171-a; monzonite-like alkaline-earth syenite	Specimen 265 alkaline-earth syenite	Specimen 1155; leucocratic alkaline-earth syenite
Size of thin section cm^2	13.5	31.5	27.5	46.0	44.0
Olivine	4.8	—	—	—	—
Augite[2]	30.2	21.9	17.3	15.0	9.2
Biotite	8.5	8.9	9.5	7.1	8.3
Hornblende	—	—	—	—	—
Plagioclase	36.9	6.4	13.2	7.9	10.5
Orthoclase	15.4	59.4	58.1	68.1	69.4
Nepheline	—	—	—	—	—
Magnetite	4.2	3.3	1.6	1.6	1.9
Apatite	isolated grains	~0.1	0.3	0.2	} 0.2
Zircon	—	—	isolated grains	0.09	
Sphene	—	—	"	—	0.5
Fluorite	—	—	—	—	
Found in grindings	Ilmenite	Ilmenite	—	—	Isolated grains Ilmenite, pyrite, quartz.

Minerals	rocks of the second phase			
	Specimen 1147; hornblende alkaline-earth syenite	Specimen 1069 pseudo-leucitic nepheline syenite	Specimen 268; biotitic nepheline syenite	Specimen 1059 biotitic nepheline syenite
Size of thin section cm^2	65.5	22.5	42.5	27.0
Olivine	—	—	—	—
Augite[2]	0.3	1.5	1.3	1.1
Biotite	0.22	1.6	4.3	3.8
Hornblende	9.9	7.7	—	—
Plagioclase	0.8	—	—	—
Orthoclase	87.9	70.8	75.0	69.0
Nepheline	—	16.8	15.6	24.3
Magnetite	0.03	1.0	1.1	0.7
Apatite	0.02 }	0.2	0.27	isolated grains
Zircon	0.23 }		0.04	"
Sphene	0.53	0.4	0.1	0.3
Fluorite	0.07			
Found in grindings	Trorianite, pyrite epidote	—	Isolated grains Mn-ilmenite, pyrite, minerals 1 and 2	Melanite

[1]The count was done on large thin sections, by L. V. Dmitriyev's method, Institute of Geochemistry and Analytic Chemistry of the U.S.S.R. Academy of Sciences.

[2]Augite is predominantly of the diopside-augite series; specimen 1171-a contained about 1.2% rhombic pyroxene.

nenite, and fluorite (rare). Sphene is a par-
ularly abundant accessory mineral, in some
alities where it is xenomorphic in interstices
ween feldspar grains.

These syenites are usually pink, with a well
fined porphyritic texture showing trachytoid
ments. Their two representatives are com-
sitionally similar to normal alkaline-earth
enites such as Norwegian akerite as well as
alkalic syenite of the pulaskite type (see
ecimens 808 and 254-b in Table 2 and Figure

On the whole, alkalic rocks of the first
ase include all possible transitional varieties
om, for example, essexite to leucocratic
artz-bearing either normal or alkalic syenite.
spite that, on the basis of general composi-
nal features and spatial distribution, these
enites are combined into distinct facies often
ving sharp boundaries. At the same time,
se features suggest that alkalic gabbroids are
oldest first phase rocks, and the leucocratic
enite facies the youngest.

Besides these features of occurrence which
phasize their younger age, syenites of the
cond stage also differ compositionally. They
e more diversified mineralogically, contain-
; a number of minerals with volatile compo-
nts: Fluorite, sodalite, and zeolites.

d) Hornblende alkalic syenites are the pre-
minant facies of the second phase. These
cks are spatially closely related to nepheline
enite and locally are nepheline-bearing.
ansitions from one kind to another take place
er short distances, through a number of inter-
ediate varieties.

Hornblende alkalic syenites are medium-
ained to coarse dark gray crystalline rocks,
th a massive to trachytoid texture. Mineral-
ically they are 80 to 95% prismatic orthoclase-
rthite, 3 to 10% black-green short-prismatic
rnblende, and 0 to 10% acid plagioclase.
rnblende is of a common variety, with a
obable addition of ferrohastingsite, especially
the peripheral zone where it commonly is
ep blue-green with a brown nucleus. Asso-
ated minerals are biotite, colorless mono-
nic pyroxene, nepheline, sodalite, and Na-
-zeolites. Nepheline, sodalite, and zeolites
ually fill up interstices in feldspar grains
thout replacing them.

Accessory minerals are sphene in idio-
orphic wedge-like crystals, short-prismatic
rcon, purple fluorite, and locally melanite,
i-andradite), and magnetite. Apatite, epi-
te, thorianite, naëgite (?), and pyrite are
re. The most abundant accessories are
hene, zircon, and fluorite.

Small pegmatoid schlieren and gently dipping veins of the same minerals as the enclosing syenite are common. These formations locally contain pocket-like bodies of sodalite (hackmanite) and zeolites. Large crystals of a pitch-black melanite (1 to 5 cm) have been observed in leucocratic schlieren zones. These melanite bodies do not appear to be metasomatic formations: there are no replacement phenomena and the K-Na-feldspar inclusions in melanite have idiomorphic outlines.

The composition of three representatives of these syenites is close to alkalic syenite of the pulaskite type (specimens 817 and 269 in Table 2 and Figure 4). The high value of c' (= 32.5) for specimen XIV is due to the presence in it of the farily abundant accessory, melanite.

e) Nepheline syenites make up about 6% of the intrusive outcrop and are associated chiefly with its northwestern edge. They are represented by coarsely crystalline, pallid light-gray rocks of a leucocratic aspect and of a predominantly massive structure. Mineralogically, they correspond to a miaskite paragenesis, being 65 to 85% orthoclase; 5 to 30% nepheline; 2 to 5% reddish-brown to greenish-black biotite, often in coarse flat scales; 1 to 3% augite pyroxene; and 0 to 9% brown-green hornblende. Because of the fluctuations in mineral composition, the following varieties may be identified: biotitic with an addition of pyroxene (predominant variety); biotite-barkevikite-pyroxene; and hornblende-biotite-pyroxene. In addition, they are subdivided into the nepheline (10 to 30% nepheline) and nepheline-bearing (5 to 10% nepheline). Acid plagioclase; Na-Ca-zeolites; colorless micas, chiefly on nepheline; and light-blue sodalite (N = 1.487) are associated minerals. For accessory minerals there are Magnetite (the most abundant), sphene, zircon, apatite, fluorite, Mn-ilmenite, pyrite, and two other minerals whose identification is lacking because of their scarcity and small amount. Mineral 1 forms glue-like xenomorphic precipitates, is greenish-brown, with a greasy luster, conchoidal fracture, low birefringence; it is radioactive and non-pleochroic. Its basic composition is Ca-Fe-Mg-silicate with Na, Al, Ti, TR. Mineral 2 forms small idiomorphic crystals, is dark-brown to reddish-brown; habit tabular or more complex; form, supposedly a triclinic syngony. Cleavage is lacking. As seen in thin section, it is brown, isotropic, with a high refractive index. Basic composition: a complex oxide of Zr, Th, and Ca, with Fe, Ti, U, Y, Ce, La, and Nb (data of semi-quantitative spectrographic analysis).

Very typical of the structure of nepheline syenites are pseudo-leucitic rounded bodies responsible for the spotty to porphyritic aspect of this rock. These bodies have no definite outlines. In a typical pseudo-leucitic nepheline

Table 2

Chemical composition of rocks of the Sandyk Mountain alkalic massif[1] (in weight %)

Components	Phase one (specimen Nos.)					Phase two (specimen Nos.)					
	1055	265	808	254-b	1050	817	XIV	269	1069	268	VI
SiO_2	53.19	56.45	59.56	61.25	68.94	58.62	58.18	59.80	55.94	57.23	57.79
TiO_2	0.78	0.57	0.58	0.54	0.12	0.62	0.69	0.76	0.72	0.46	0.62
Al_2O_3	15.44	17.26	17.40	17.29	16.11	19.75	19.46	18.64	19.67	20.51	17.61
Fe_2O_3	3.10	2.33	2.28	2.47	1.13	1.34	1.44	2.34	0.98	1.27	2.45
FeO	4.49	3.66	2.72	1.44	0.47	2.31	1.96	1.37	2.45	1.43	2.90
MgO	6.25	3.83	2.34	1.19	0.15	1.25	0.40	0.63	1.38	0.66	2.66
CaO	7.90	5.87	4.11	2.52	0.54	2.73	2.57	1.99	2.63	1.68	4.61
Na_2O	2.55	3.05	3.56	2.53	3.72	3.40	3.70	3.12	2.39	2.32	3.00
K_2O	5.45	6.12	6.66	9.46	8.44	10.02	10.37	9.87	12.84	12.44	7.69
Losses in heating	0.76	0.52	0.44	0.79	0.48	0.78	0.89	1.16	0.78	1.40	0.67
Total ξ	99.91	99.66	99.65	99.48	100.10	100.82	100.66	99.68	99.78	99.40	100.00
$\frac{RO}{R_2O}$	2.33	1.45	0.9	0.43	0.09	0.47	0.35	0.30	0.42	0.25	0.95
$\frac{R_2O+RO}{SiO_2}$	0.5	0.4	0.32	0.27	0.19	0.33	0.32	0.28	0.38	0.32	0.36
$\frac{K+Na}{Al}$	0.65	0.64	0.75	0.82	0.94	0.83	0.89	0.85	0.9	0.84	0.75
$\frac{Na}{Al-K}$	0.43	0.47	0.56	0.58	0.87	0.63	0.75	0.65	0.7	0.53	0.52
Recomputation by the A. N. Zavaritskiy method											
a	13.2	15.8	17.5	19.6	20.2	22.5	24.0	21.9	24.7	24.4	17.9
c	3.55	3.7	3.1	2.0	0.6	2.2	1.4	1.9	1.3	2.2	3.0
b	23.1	15.2	10.5	6.8	1.7	6.6	5.6	5.0	7.7	4.0	12.1
s	60.15	65.3	68.9	71.6	77.5	68.7	69.0	71.2	66.3	69.4	67.0
a'	—	—	—	—	—	—	—	—	—	7.3	—
f'	29.2	35.3	43.2	53.0	80.8	50.6	55.0	66.2	42.2	63.7	40.0
m'	45.0	42.5	37.2	30.6	15.4	32.6	12.5	21.1	32.1	29.0	37.7
c'	25.8	22.2	19.6	16.4	3.8	16.8	32.5	12.7	25.7	—	22.3
n	41.4	43.0	44.8	28.5	40.3	34.1	38.2	32.2	22.3	21.8	37.0
Q	—9.65	—4.7	—0.3	+2.0	+14.0	—9.8	—11.4	—3.3	—18.1	—12.2	—4.8
a : *c*	3.7	4.3	5.6	9.8	33.7	10.2	17.2	11.5	19.0	11.1	6.0

Rocks of the first intrusive phase: specimen 1055—essexite-augite-biotite monzonite, olivine-bearing (early facies "a"); specimen 265—porphyritic to alkaline-earth monzonitic syenite, augite-biotite (main facies "b"); specimen 808—strongly porphyritic augite-biotite normal alkaline-earth syenite (late facies "c"); specimen 254-b—strongly porphyritic leucocratic syenite, biotite-(epi)hornblendic, pyroxenic (late facies "c"); specimen 1050—aegirine-augite quartz syenite-aplite (vein series).

Rocks of the second intrusive facies: specimen 817—coarse-grained massive hornblende alkalic syenite (early facies "d"); specimen XIV—medium-grained trachytoid hornblende alkalic syenite with melanite (early facies "d"); specimen 269—medium-grained leucocratic hornblende alkalic syenite (early facies "d"); specimen 1069—pseudo-leucitic porphyritic nepheline syenite, hornblende-pyroxene-biotitic (late facies "e"); specimen 268—massive nepheline syenite, biotitic with augite (late facies "e"); specimen VI—average computed composition of magma for the Sandyk Mountain intrusion.

[1] Silicate analyses performed by L. A. Pevtsova at the Institute of Geochemistry and Analytic Chemistry, Academy of Sciences, U.S.S.R. The K and Na content in specimens 817, XIX, and 1069 were determined by flame photometry by V. I. Lebedev, at the same institution.

enite, these light-colored rounded bodies nsist of fine, fairly idiomorphic prismatic ystals of orthoclase cemented with nepheline igure 2). In hypidiomorphic-granular massive nepheline syenite, such accumulations are cognized either on weathered surfaces of a mp or else only under the microscope, when

FIGURE 2. Structure of a pseudo-leucitic body.
A drawing of thin section; 5 x; single Nicol.

1) nepheline; 2) orthoclase; isolated grains of hornblende and biotite scales are present.

ey are not as well defined. Here, nepheline preads out of pseudo-leucitic bodies and into e adjacent rock where it fills up interstices etween coarse crystals of orthoclase, which oints to its late crystallization (Figure 3). onsequently, the observation data suggest a rimary-magmatic nature of the pseudo-eucitic aggregates. It appears that they riginated as "liquid crystals" of a leucitic omposition, and then crystallized out as epheline and orthoclase, in the process of rystallization of the rock as a whole.

Conspicuous among other features of the epheline syenite is a late formation of bio-te in fine scales which are found between eldspar grains, without replacing them.

The lenticular occurrence of nepheline yenite in varieties of hornblende or else their osition below alkaline-earth syenites in deeper egments of the intrusive body, along with oorly developed prototectonic phenomena and e presence of these peculiar pseudo-leucitic ggregates all suggest that nepheline syenites ere formed the last and under conditions of dying-out intrusive process.

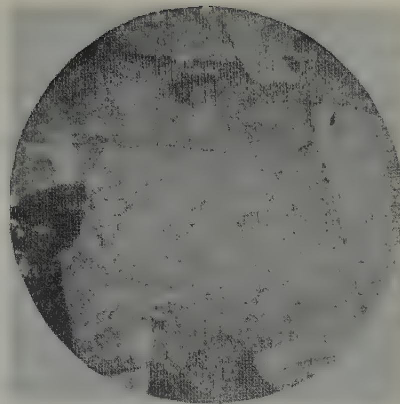

FIGURE 3. Usual relationship of nepheline (1) and orthoclase (2) in nepheline syenite. 10 x; Crossed Nicols.

Two specimens of nepheline syenites (Nos. 268 and 1069, Tables 1 and 2, and Figure 2) are similar to miaskite, petrochemically and mineralogically. The definite predominance of K over Na (n = 22) and the generally high K content is very conspicuous. The leucocratic composition of nepheline syenite with a high content of K_2O (up to 12%) and of Al_2O_3 (up to 20%) suggests that they may be a possible source of aluminum, potash, and portland cement.

This brief petrographic sketch of alkalic rocks in the Sandyk Mountains brings forth a peculiar feature of the zonation in the intrusive body: its deeper zones, made up of the second phase rocks, are on the whole more leucocratic than the peripheral and apex parts which are enriched in dark minerals (Table 1).

The vein series of this intrusion is but developed slightly, being represented by both melanocratic and leucocratic rock types, chiefly of the syenite series. In composition, they appear to inherit many typical features of the composition of their source rocks of both phases. Thus, K-Na-feldspar is sharply predominant or is even the single principal sialic mineral. In vein monzonite, monzonite porphyr, syenite porphyr, and in many leucosyenites, dark minerals are represented by diopside-augite and biotite. In syenite-aplite and bostonite, rare dark minerals commonly are aegirine-augite and biotite, with quartz not uncommon, as are accessory to 5 ot 10%. These vein rocks usually are found among the first phase syenites.

In intrusive syenite of the second phase (in alkalic hornblende and nepheline and nepheline syenites), vein rocks are usually

more alkalic and leucocratic. Thus, arfvedsonite hornblende is present in them, with nepheline, sodalite, hackmanite, and zeolites commonly present instead of quartz. For example, a peculiar variety of bostonite consisting of elongated crystals of K-Na-feldspar, with interstices filled with nepheline, sodalite, and fluorite with a small addition of biotite was observed among nepheline syenites.

It appears that a consecutive formation of vein derivatives took place during and after the intrusion differentiation into its main rock types. However, the absence of intersections of vein rocks makes it impossible to make this assumption more specific. It is quite possible that some of the vein rocks in syenites of the first phase are derivatives of the second phase; this may be especially true for syenite porphyr with incrustations of epi- and pseudo-leucite and for a portion of syenite-aplite and feldspathic bostonite. The injectional occurrence of all vein rocks suggests their igneous origin.

GEOCHEMICAL FEATURES OF THE INTRUSION

Foremost among geochemical features of alkalic rocks in the Sandyk Mountains intrusion is their peculiar alkalinity. Thus all compositions are marked by a considerable K_2O content and by a predominance of K_2O over Na_2O ($n = 22$-45), as compared with median types of alkalic rocks of a similar composition. The potassium alkalinity is graphically illustrated by a very flat slope of vectors in the left part of the diagram (Figure 4). This is accompanied by an absolute accumulation of K_2O in later differentiates, approximately twice as large, reaching 10 to 12% in syenites of the second phase, and by a more or less constant and low Na_2O content varying but slightly at about 3%. Only the mineralogic forms of sodium fixation change; it is plagioclase and orthoclase for rocks of the first phase; chiefly orthoclase-perthite for hornblende alkalic syenites of the second phase; and mostly nepheline for nepheline syenites. It is possible that manifestations of sodium metasomatism are not typical of this intrusion because of this very low sodium content and the lack of a tendency for its accumulation in the process of differentiation.

Alkalic rocks of the Sandyk Mountains intrusion have a normal geochemical composition, ($CaO+Na_2O+K_2O > Al_2O_3 > K_2O+Na_2O$); only a few nepheline syenites are slightly oversaturated in alumina, such as leucocratic nepheline biotite syenite (specimen 268; a'= 7.3). In the course of the development of the intrusion, the alumina content increased from older (alkalic gabbroid) to younger (nepheline syenite) rocks, to attain 20% Al_2O_3 in the nepheline syenite, which may be correlated with the above-mentioned alkaline conditions and whose cause might have been the progressive accumulation of potassium.

Most of these rocks are marked by a low saturation in SiO_2 as expressed in the negative value of Q and in the appearance of olivine, nepheline, and sodalite. Some of the vein rocks, such as aplite-syenite in specimen 1050 (Table 2) are slightly supersaturated with SiO_2 and carry quartz. Some leucocratic syenites of the first phase are petrographically similar to the second-phase rocks. However, the first are marked either by a positive or a very low negative value of Q which is expressed in the appearance of accessory quartz. On the other hand, the chemically similar second-phase rocks (in alkalic hornblende syenite) are marked by a lack of quartz and by a fairly considerable deficiency in SiO_2. Here, Q has a higher negative value accompanied by the appearance of nepheline. This is related to the fact that there was an increase in SiO_2 accompanied by a decrease in the ratio $(R_2O + RO)/SiO_2$, in the series of consecutive differentiates of the first phase, from oldest rocks (alkalic gabbroid) to the youngest (leucocratic syenite). Syenites of the second phase, on the other hand, displayed a lower alumina content for the same values of this ratio. This is directly related to the alkalie plus alkaline-earth ratio to iron, in the process of differentiation.

The fact is that a characteristic feature of differentiation, in this case, is the strong antagonism of alkaline-earths for alkalies. Ratio RO/R_2O decreases sharply from older rocks (alkalic gabbroid) to the younger (leucocratic syenite facies of the first phase and rocks of the second phase): by a factor of 2 to 3 for monzonite-essexite and by a factor of 3 to 9 for younger differentiates (Figure 4). The vector diagram shows an evolution of the composition points upward and to the right: index b decreases by a factor of 3 to 5 as a increases nearly twice, with the rise in alkalinity caused by an accumulation of K for a lower content of Ca, Mg, and Fe.

Thus a comparison of geochemical indexes for rocks of the first and second phases emphasizes their distinctive features as reflected in changing values of b, a:c, RO/R_2O and R_2O+RO/SiO_2. Thus the first phase is characterized by a moderate saturation in alkalies ($7 > a/c > 2$) while the deficiency in SiO_2 is present with regard to alkaline-earths and iron, as demonstrated by the negative value of Q for high values of ratio RO/R_2O and a larbe b. Ferrous-magnesian olivine appears here.

Rocks of the second phase are richer in alkalies (a:c>7) and have a deficiency in SiO_2 as shown by their negative value of Q and a low RO/R_2O ratio. Nepheline appears here at values of b considerably lower than in the first phase rocks.

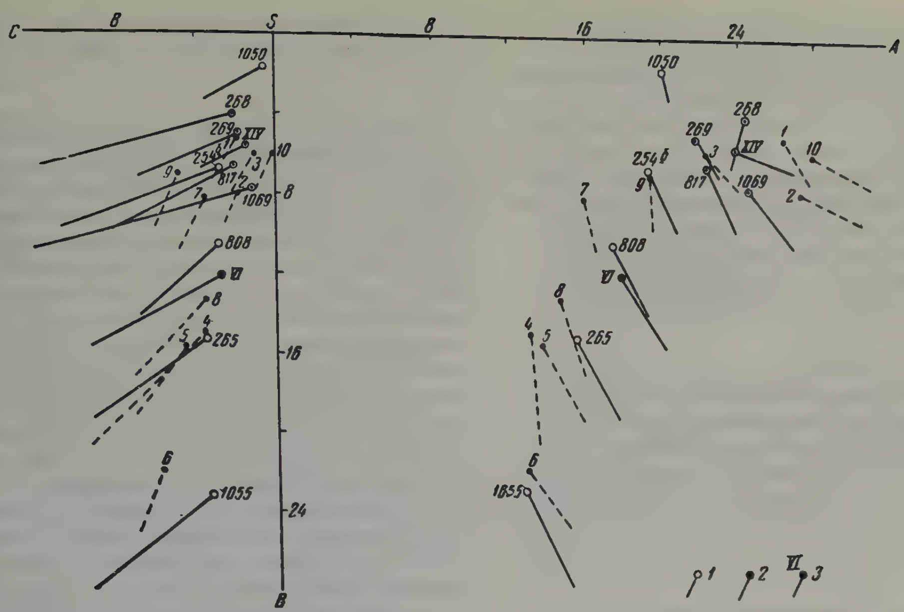

FIGURE 4. Vector diagram of the composition of alkalic rocks in the Sandyk intrusion as compared with some median types of alkalic rocks (solid vector lines-the Sandyk rocks; dashed lines-median types).

1 - rocks of the first intrusive phase; 2 - rocks of the second intrusive phase; 3 - average computed composition of the original alkalic magma of the Sandyk intrusion; Names of the intrusive rocks are given for the corresponding numbers in Table 2. For median types: 1 - average of 11 analyses of Uralian miaskites, by V.I. Luchitskiy (9, p. 264, analysis I); 2 - miaskite, by B.M. Kupletskiy (7, p. 370, analysis III); 3 - pulaskite, by R. Daly (7, 324, analysis VI); 4 - monzonite, by R. Daly (7, p. 324, analysis XI); 5 - micaceous alkaline-earth syenite, by R. Daly (6, p. 347, analysis 15); 6 - essexite, R. Daly (6, p. 349, analysis 93); 7 - akerite, R. Daly (7, p. 324, analysis VII); 8 - alkaline-earth syenite of all types, by R. Daly (6, p.347, analysis 17); 9 - laurvikite, by R. Daly (7, p. 324, analysis X); 10 - foyaite, by R. Daly (7, p. 370 analysis IV).

The presence in the second phase syenites, such volatile-bearing minerals as fluorite, odalite, zeolites, and hornblende indicates a reater degree of saturation in volatiles (F, Cl, $_2$O) in this phase, compared with the first hase.

To explain the paragenesis of dark minerals these rocks we introduced an additional ctor (Na) = Na/(Al-K) which determines the ossibility of the formation of alkaline pyroenes and amphiboles for given ratios of Na, , and Al. Here, (Na) is the ratio of Na atoms that number of Al atoms which remains in a elt after the saturation of aluminosilicates by uminum, to the ratio K:Al = 1:1. Inasmuch as a/Al = 1/1 in albite and nepheline, the value (Na) should indicate the degree of an excess deficiency in Na with relation to aluminum d, consequently, the possibility of the forration of Na-rich dark minerals (aegirine, fvedsonite, and riebeckite).

As it turns out, the value of (Na) for the ain types of alkalic rocks in the intrusion is 43-0.75, considerably less than one. As seen in Table 2, these values are more indicative of the plumasite nature of these rocks than their agpaitic coefficients. As has been noted before, Na-rich dark minerals are not typical of these rocks where the usual association is augite, biotite, and common hornblende, i.e., minerals showing an excess alumina with regard to alkalies. By the same token, the presence of biotite, augite, and the higher basicity of plagioclase in alkalic gabbroids and alkaline-earth syenites determines the minimum value of (Na) (0.43-0.56) for these rocks. On the other hand, the excess Na in the formation of Na-rich dark minerals suggests a limited combination of Na^+, Fe^{3+}), as in aegirine. Because of that, a considerable amount of Fe^{3+} is cast off to form accessory magnetite. It has been demonstrated that this mineral is most common and most abundant in alkalic rocks of the intrusion. On the other hand, the appearance of aegirine-diopside in syenite-aplite (specimen 1050) is reflected in a higher value of (Na) = 0.87 for that sample and is accompanied by a lower accessory magnetite content, as compared with biotite syenite-aplites.

In summing up, it can be stated that geochemical study of the zoned di-phase plutonic body of the Sandyk Mountains suggests a definite direction of evolution of the alkalie melt, in time and space. A consecutive differentiation of the emplaced alkalic magma into a number of compositions took place during that very formation of the intrusion. The earlier of these compositions were enriched in mafic components, Fe, Mg (and Ca); they were undersaturated in SiO_2 and relatively poor in volatiles. They make up the upper and the peripheral parts of the intrusion and correspond on the whole to the first-phase rocks.

The later compositions were poor in Fe, Mg, and Ca; considerably richer in K; undersaturated with SiO_2 with relation to alkalies; and relatively richer in volatile components. They are located in deeper reaches of the intrusive body and correspond on the whole to the second phase rocks.

THE PROBLEMS OF ORIGIN

Geologic conditions of occurrence of this intrusion, and its structural features, preclude the application of R. Daly's hypothesis and any similar view for an explanation of the origin of the Sandyk intrusion. Furthermore, there are no data on a probable genetic relationship between the alkalie magma and either the granitic or the basic. As a consequence, alkalic gabbroid and nepheline syenite cannot be regarded as product of assimilative interaction of a granite magma with rock rich in bases (limestone or other Ca-Mg-Fe-rocks), with a resulting desiliconization of the hybrid melt. The reasons for this follow.

Lower Paleozoic carbonate rocks of this area are developed south of the intrusion and are separated from it by Lower Silurian sandstone and slate. Nepheline syenites are distributed mostly along the northern edge of the intrusive body, in its interior parts. Alkalic gabbroid is present at the intrusive contacts with both Lower Silurian sandstone and slate and with Caledonian granitoids — both considerably inferior to them in Ca, Mg, and Fe content. Xenoliths of the enclosing and deeper rocks are rare in the intrusive rocks and there are no primary carbonates among their minerals, including the nepheline syenites.

It is especially significant that the SiO_2 deficiency is most marked in both the primary products of differentiation and in the later ones, which militates against a desiliconizing effect caused by external factors. In intermediate varieties, the SiO_2 deficiency is not as conspicuous. Also, a treatment of the origin of these rocks as the result of metasomatic processes with a participation of highly alkaline potassium fluids is without justification, inasmuch as the demonstrated relationship of rocks and minerals is more typical of igneous formations.

Accordingly, the primary nature of the Sandyk Mountains alkalic magma and its derivatives must be assumed. The composition of this magma was calculated approximately from chemical analyses of typical rock representatives, taking into account the area of their distribution (see analysis VI in Table 2, and Figure 4). The composition of this alkalic mother magma was close to alkaline-earth syenite, in its considerable K content as compared with Na ($n = 37.0$); in its RO/R_2O ratio close to 1 (0.95); a higher Ca content; and some deficiency in SiO_2 ($Q = -4.5$). Differentiation of such magma could have taken place within an intrusive chamber and the feeding channels, without any material being added or taken away. It is in this process that the antagonism, frequently mentioned by F. D. Levinson-Lessing [8] for alkalies toward alkaline-earths, among factors of magmatic differentiation, became manifest; in our study, it was expressed in the formation of mesocratic melts of the first phase and of more alkalic and leucocratic derivatives of the second phase. What is, then, the mechanism and the causes of such differentiation?

As has been shown by the experimental study of D. P. Grigor'yev, Ya. I. Ol'shanskiy, and Z. P. Yershova [2, 3, 4], the liquation of a silicate melt into a leucocratic and a mesocratic composition of a limited miscibility and with a mandatory and prompting action of volatile substances (especially fluorine) is quite possible. It should be noted that such an effect could hardly have been unique, inasmuch as the presence of a definite zonation in the intrusive structure calls for additional explanation and does not follow from a liquational differentiation. It is possible that the influx of Fe, Mg, and Ca to upper levels of an intrusive magma from its deeper and hotter reaches was of a thermo-diffusive nature. It can be supposed that both thermo-diffusion and liquation were the main factors of magmatic differentiation of an alkalic magma of the Sandyk intrusion. A detailed consideration of these complex problems is beyond the scope of this paper.

However, this interpretation of the origin of nepheline syenite is of importance as a prospecting criterion because it puts among the sources of these industrially valuable rocks those alkalic intrusions of a complex composition which are not related to carbonate or other rocks of a higher basicity, and which have hitherto been believed valueless.

SUMMARY

1. The Sandyk Mountains alkalic intrusion belongs to complexly differentiated plutonic

odies of a two-phase development and hypa-ssal occurrence of the fracture type, in the rthern Tyan'-Shan' Caledonian rocks. Its other magma was close in composition to kaline-earth syenite, much richer in K than Na, and without any direct genetic relation-ip to a granitic or a basic magma. A geologic d petrochemical study of the assorted alkalic cks in this intrusion demonstrates their ge-tic kinship and a near-contemporaneous igin.

2. Nepheline syenite of the miaskite type d their peculiar pseudo-leucitic varieties re discovered here, the first for northern shkiriya. These rocks have a leucocratic pect, a high K and Al content, and may be of dustrial value.

3. The differentiation process for an alkalic agma in the development of the intrusion is arked by a well-defined, strong antagonism tween alkalies, chiefly K, and alkaline-rths, on one hand, and iron on the other. is is reflected in a zonal structure of the trusive body. The oldest rocks are located the upper and outer parts of the intrusion here they are enriched considerably in Ca, g, and Fe. The youngest rocks form the terior parts; they are low in Ca, Mg, and Fe, d rich in K, Al, and volatiles.

4. The application of factor (Na) = Na/(Al - which expresses the deficiency in Na relative Al has brought out the petrochemical features the several compositions, determining the pearance of typical plumasite dark minerals alkalic rocks of the intrusion.

5. The R. Daly hypothesis is inoperative explaining the origin of various alkalic rocks the intrusion. It is surmised that phenomena thermal diffusion and liquation have been the ain factors of differentiation of the alkalic agma.

REFERENCES

1. Gerasimovskiy, V. I., Geokhimiya i mineralogiya nefelino-siyenitovykh intruziy [GEOCHEMISTRY AND MINERALOGY OF NEPHELINE-SYENITE INTRUSIONS]: Geokhimiya, no. 5, 1956.

2. Grigor'yev, D.P. and Ye.V. Iskyul', Differentsiatsiya nekotorykh silikatnykh rasplavov kak rezul'tat obrazovaniya dvukh nesmeshivayushchikhsya zhidkostey [DIFFERENTIATION OF SOME SILICATE MELTS AS A RESULT OF THE FORMATION OF TWO IMMISCIBLE LIQUIDS]: Izv. AN SSSR, Ser. Geol., no. 1, 1937.

3. Yershova, Z.P. and Ya.I. Ol'shanskiy, Ravnovesiye nesmeshivayushchikhsya zhidkostey v sistemakh tipa: $MeFe_2$ —MeO —SiO_2 [EQUILIBRIUM OF IMMISCIBLE LIQUIDS IN SYSTEM OF TYPE $MeFe_2$-MeO —SiO_2]: Geokhimiya, no. 3, 1957.

4. Yershova, Z.P., Ravnovesiye nesmeshivayushchikhsya zhidkostey v sistemakh tipa: MeF_2 —Al_2O_3 —SiO_2 [EQUILIBRIUM OF IMMISCIBLE LIQUIDS IN SYSTEMS OF THE TYPE Me F_2 —Al_2O_3 —SiO_2]: Ibid, no. 4, 1957.

5. Zavaritskiy, A.N., Vvedeniye v petrokhimiyu izverzhennykh porod [INTRODUCTION TO THE GEOCHEMISTRY OF EXTRUSIVE ROCKS]: Izd. AN SSSR, 1950.

6. Zavaritskiy, A.N., Izverzhennyye gornyye porody [EFFUSIVE ROCKS]: Izd. AN SSSR, 1955.

7. Kupletskiy, B.M., Formatsiya nefelinovykh siyenitov SSSR [FORMATION OF NEPHELINE SYENITES OF THE USSR]: In Petrografiya SSSR, Monografii, vyp. 3, 1937.

8. Levinson-Lessing, F.Yu., Izbrannyye trudy [SELECTED WORKS]: Vols 1-2, Izd. AN SSSR, 1949-1950.

9. Luchitskiy, V.I., Petrografiya [PETROGRAPHY]: t. 2, Gosgeolizdat, 1949.

10. Pomazkov, K. D., O roli tektonicheskikh struktur v razmeshcheniya gertsinskikh intruziy Severnogo Tyan'-Shanya [THE ROLE OF TECTONICS STRUCTURES IN THE DISTRIBUTION OF HERCINIAN INTRUSIONS IN NORTHERN TYAN'-SHAN']: Dokl. AN SSR, t. 122, no. 5, 1958.

11. Sinitsin, N.M., Skhema tektoniki Tyan'-Shanya [TECTONICS OF TYAN'-SHAN']: Vestn. Leningr. Univ., Ser. Geol. i Geogr., no. 12, 1957.

The V. I. Vernadskiy Institute
of Geochemistry and Analytic Chemistry,
the U.S.S.R. Academy of Sciences,
Moscow

Received May 26, 1958.

BORIS VASIL'YEVICH IVANOV (OBITUARY)[1]

Boris Vasil'yevich Ivanov died on the night of October 11, 1959, after a grave illness; his untimely death came in his 53-rd year. He was Senior Scientist of the Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry (I. G. E. M.), the U. S. S. R. Academy of Sciences, and Candidate of Geologic and Mineralogic Sciences. In losing B. V. Ivanov, Soviet science has lost an outstanding expert in the field of petrography of industrial rocks. After having graduated in 1930 from the Geochemical Division of Leningrad Polytechnic Institute, B. V. Ivanov started his scientific career by working on exploration for non-ore minerals (mica, feldspars) in Kareliya, at the Karelgranit Trust. Having taken a liking to the North, he became interested in the minerals of Kareliya and the Kola Peninsula and he kept up this interest and close scientific connections with the Kola Affiliate of the U. S. S. R. Academy, until the end of his life.

In 1934, B. V. Ivanov was invited by Academician D. S. Belyankin to work at the Academy in the organization then termed Section of Technical Petrography at the Petrographic Institute. From then on and to the very end, his work was connected exclusively with that branch of petrographic sciency developed in the I. G. E. M. Scientific achievements of B. V. Ivanov are reflected in some 70 published original studies, chiefly on the chemistry and mineralogy of refractory materials and on minerals used in producing them.

A distinctive feature of his work was the close relation of theoretical and practical problems and the striving to utilize new scientific data in the solution of specific industrial problems. For that reason, his creative, and friendly relations with industrial organizations and industrial institutions for scientific research were extensive, close, and fruitful. The faultless accuracy of his data and the rigor of his scientific formulations gained wide recognition among the experts in allied fields and made his reputation as an authority.

B. V. Ivanov was a lover of books. He was well versed in scientific literature and was on the list of the Moscow scientific libraries in his field of work. His interest in literature was combined with an outstanding memory; he well deserved his reputation as an erudite man in the field of technical petrography.

His ability and industry were not confined to scientific work alone but extended to the field of organization. At various times he was on the Board of Directors of the I. G. E. M. (Active Scientific Director); Academic Secretary of the Section of Geologic and Petrographic Sciences, Acting Chief of the Special Task Section; on the Editorial Board of Izvestiya of the U. S. S. R. Academy of Sciences, Geologic Series (Managing Secretary); Acting Chairman of the Organization Committee, Conference for Experimental and Technical Mineralogy and Petrography, and on the Editorial Board of magazine "Ogneupory." He was frequently commissioned to inspect the activity of various Affiliates of the Academy.

For his scientific endeavors, B. V. Ivanov was awarded orders of the Red Star and the "Order of Merit."

His outstanding discipline and organizational ability earned him a rapid promotion in the Soviet Army, in whose ranks he fought from the first to the last day of the Great Patriotic War. He went into the army as a lieutenant and came out a lieutenant colonel; he was awarded for his combat services the Order of Patriotic War, First and Second Class, the order of the Red Banner, and medals "For Combat Service" and "For Victory Over Germany."

B. V. Ivanov has made a large contribution to science. His works in petrology of technical

[1]Boris Vasil'yevich Ivanov.

cks will long serve as a model and manual for perts in that field.

The friendly image of B. V. Ivanov will always live in the hearts of his friends, coworkers, and pupils.

G. A. Afanas'yev,

V. V. Lapin,

A. I. Tsvetkov

REVIEWS AND DISCUSSIONS

ON MOVEMENTS OF THE EARTH'S CRUST IN THE SAKHALIN REGION, BETWEEN THE LATE CRETACEOUS AND THE PALEOGENE[1]

by

A. A. Kapitsa

Doklady of the Academy of Sciences, U.S.S.R. (vol. 119, No. 4, 1958, p. 766) carries a paper entitled, The Lack of a Break in Sedimentation Between the Cenozoic and Mesozoic in the Sinegorsk-Zagorsk Area, Sakhalin, by T. G. Kalishevich and V. Ya. Posyl'nyy. The authors set out to prove, on the basis of simple generic identification of the fossil fauna that a 650-m sequence between definitely Senonian beds of the Orochensk stage with Parapchydiscus, Inoceramus, etc., and Paleogene Lower Duysk coal-bearing beds, is Paleocene to (presumably Danian. In their opinion, the difference between Paleocene and Danian beds is that the Paleocene carries Malletia and Voldia, which are missing in the Danian which carries Trochocyathus instead. Such a condition is not only without logical foundation but obviously at a va variance with direct and indirect evidence which the authors unfortunately have disregarded.

Indeed, in calling the Lower Duysk formation "Eocene," they did not take the trouble to prove its Eocene age. Now, A. N. Krishtofovich states ([1], p. 232) on the subject of this formation in northern Sakhalin: "If the Lower Duysk beds are Upper Eocene, the Upper Duysk beds were deposited in the Oligocene, perhaps before its end; if, on the other hand, the Lower Duysk beds were deposited as late as the Oligocene, the end of the Upper Duysk deposition presisted into early Miocene." In his time, A. A. Kapitsa and his co-workers, L. M. Sayapina, P. D. Sklyayev, and others, proved with abundant data the identity of the Paleogene coal measures of northern and southern Sakhalin, including the Zagorsk-Sinegorsk coal measures - the Naibuchi formation of Japanese geologists which they were inclined to assign to the Oligocene but not to the Eocene [2].

Thus, the problem of the geologic age of the Lower Duysk formation cannot be regarded as definitely solved.

There is no doubt that this formation, on the whole, is Paleogene and at the same time younger than the Paleocene Akadzaki beds and lower Middle Eocene nummulitic beds and formations in the Hondo and Motodovari, Japan. On the other hand, no beds correlative with these ancient Paleogene ones have yet been found on Sakhalin; nor are they likely to be found because Paleogene transgression proceeded from Japan, i. e., from the south.

With regard to the so-called "Paleocene" formation of the authors, it cannot even be Danian, because I found an ammonite contradicting that, in the valley of Naybe River, in Campanian tuffaceous beds, a typical Paleogene fauna, of the Orochensk stage, 50 m below the Lower Duysk formation soil.

Finally, the so-called "Danian" beds of these authors belongs really to a Senonian (Orochensk) stage which, along with Trochacyathus typical of it and of a somewhat lower horizon, carries Inoceramus and other fossils which we have found in a number of localities throughout the western Sakhalin Range.

As a matter of fact, fossils cited by the authors (identified to genera only and not to species!) as a proof of a "Danian" and "Paleocene" age of the 650-m thick sequence have a very wide stratigraphic range, from the Mesozoic and even Paleozoic through the Cenozoic. Such a "basis" for an age determination of beds is more than precarious.

Because of an ancient erosion, the thick maastrichtian volcanic-sedimentary Boshnyakov formation, known north of this area in the western Sakhalin Range and in the eastern part of the island, is missing in the Zaborsk-Sinegorsk

---

[1]K voprosu o dvizheniyakh zemnoy kory v oblasti Sakhalina na granitse verkhnemelovoy i paleogenovoy epokh.

ɔer Cretaceous section. That formation, ch we have long since identified as the upper-st member of the Orochensk stage, carries monites and inocerami along with a typical ɔer Cretaceous flora of ferns, nilssonias, many other pre-Tsagayan (pre-Danian) ınts.

There is no doubt that this volcanic sequence, identally, corresponding to Senonian vol-ıics of Kamchatka, Japan, and the Amur-suri Province, is younger than the 650-m ck section of the two authors. This author, ng with other Soviet and Japanese geologists, long since and incontravertibly proven the ıerally unconformable position of the Paleo-ıe Lower Duysk formation on various Senon- horizons, in Sakhalin.

In Japan, beds correlative with the Lower ysk formation rest unconformably on much er rocks. Unconformable occurrences of ious Paleogene beds on different Senonian izons has long been observed not only in khalin but in Kamchatka and the Amur-Ussuri ɔvince as well. They all suggest the regional ure of diastrophism which took place between Late Cretaceous and the Paleogene in the ɔan-Okhotsk geotectonic province. This is the in reason for the abrupt changes in Paleogene ına and flora, compared with the Upper Cre-ceous. The authors' conclusions on the al-ged absence of a Mesozoic-Cenozoic sedimen-y break in the Zagorsk-Sinegorsk area run ainst firmly established stratigraphic and ctonic views. We hope that this criticism ll be supported by experienced geologists who ve spent some years in the study of the Japan-hotsk tectonic region.

REFERENCES

. Krishtofovich, A.N., Geologicheskiy obzor stran Dal'nego Vostoka. [GEOLOGIC REVIEW OF THE FAR EASTERN COUNTRIES]: Geolrazvedizdat, 1932.

. Uwatoko, Kunio, GEOLOGIC MAP OF SOUTH SAKHALIN AND ITS EXPLANATORY TEXT. (Scale, 1:500,000). Journ. Geol. and Geogr. Japan, vol. 18, No. 1, 2, 1940.

ON V. D. KOGAN'S PAPER "ORIGIN OF NATIVE SULFUR"[1,2]

by

P. M. Murzayev

The origin of sulfur, one of the most im-rtant minerals, is not yet known. A proof of this among other things, is the paper under review. The importance of the problem of exploration and prospecting requires no explanation. In addition, its solution will affect the creation of synthetic sulfur deposits.[3] In his attempt to help clarify this obscure subject, V. D. Kogan "approached it from a different point of view," not yet taken up in numerous works on the origin of sulfur. This new approach he states as follows: "If some sulfur ores have been formed in a replacement of gypsum, and others formed in a replacement of limestones, then. . . 1) accessory minerals of Group I (coarsely crystalline sulfur ore) should be correlative with accessory minerals of gypsum; 2) accessory minerals of Group II (dispersion) ores should be correlative with those of limestones."

The author does not explain what sulfur ores are referred to, what kind of replacement he is talking about (physical or chemical?), or what relationship exists between ores of groups I and II and other rocks.

To substantiate his point, the author gives a table of the distribution of accessory minerals in ores of groups I and II, gypsum, and limestone of the Gaurdak sulfur deposit. It shows the similarity in accessory minerals of gypsum and those of sulfur ores of Group I; and of limestone accessory minerals and ores of Group II.

From there, the author goes on to the conclusion that "at least some of the dispersion ores have been formed in a direct replacement of anhydrite (by way of gypsum) by sulfur ore."

The lack of correspondence between the premise and the conclusion is striking; there is no explanation to that effect in the paper.

According to the text and the Table, accessory minerals of the dispersion ores differ from those of gypsum; this, however, contradicts the direct replacement of the latter. Indeed, if an ore (sulfur with the enclosing rock?) is epigenetic in relation to the enclosing rock and is a product of its chemical metasomatism, the accessory minerals of both should be similar in composition, as is the case of a syngenetic ore. Apparently the author has not taken that into consideration; for this reason, "material

[1]Po povodu stat'i V. D. Kogana "K genezisu samoınoy sery."

[2]Dokl. AN S.S.S.R., t. 125, no. 5, 1959.

[3]Dzens-Litovskiy, A. I., The Problem of Creating Synthetic Mineral Deposits. Priroda, no. 11, 1955.

cited" does not prove that "at least some of the dispersed ores have been formed in a direct replacement of anhydrite (gypsum) by sulfur ore."

The author should have made a distinction tween the formation of primary sulfur and of sulfur recrystallized and added to that deposit; he also should have taken into consideration the high chemical activity and mobility of sulfur.

The author may be right in stating that coarse crystalline sulfur of sedimentary deposits is epigenetic, but only with relation to primary dispersion sulfur and always in relation to the enclosing rocks.

LETTER TO THE EDITORIAL BOARD ON THE CRITICISM OF THE STATUS OF GEOLOGIC SCIENCE[1]

by

V.I. Smirnov,
Corresponding Member of the Academy of Sciences, U.S.S.R.

Izvestiya of Schools of Higher Learning, Geology and Exploration, No. 8, 1959, carries an article by P. Ya. Antropov, On Some Aspects of Geologic Science in Connection with the Seven Year Plan for the Development of the State Economy in the U.S.S.R.

In extending the scope of his criticism, P. Ya. Antropov includes in his article Yu. A. Bilibin, G. Scheneiderchen, and myself. His blanket accusation, which also extends to a large number of geologists, is no less that our views "not only do not promote and facilitate the study of the geology and minerals of this or that area but actually complicate and definitely confuse it" (p. 14). Leaving this conclusion to the judgment of geologists, we should like to clarify some of the points touched upon in the article.

In view of the fact that P. Ya. Antropov's article does not differentiate the concepts of Yu. A. Bilibin, G. Schneiderchen, and myself, lumping them together as "erroneous views disorienting the production," I deem it necessary to present a brief resume of the differences in scientific concepts between the three of us. I must beg the reader's indulgence for this digression: the only reason for it is that P. Ya. Antropov did not clarify this point.

As is well known, Ya. A. Bilibin recognized a single cycle of geosynclinal development, for all folded provinces; he divided it into three stages, in his early works, and into five in his later works. He ascribed to each stage its proper igneous complexes and the formations of endogenic minerals. In that respect, he was a monycyclist. It is also known that there was no lack of criticism of his scientific concepts. I myself noted their specific weak points. But I categorically disagree with P. Ya. Antropov that Yu. A. Bilibin's development scale was scholastic, presenting neither a theoretically worked-out scientific basis nor the practical results of generalization of empirical facts (p. 5). For myself, I have regarded and do regard now Yu. A. Bilibin as an outstanding scientist who has advanced the study of metallogeny and of the conditions of formation of industrial minerals.

Unlike Yu. A. Bilibin, G. Schneiderchen believes that folded provinces and associated mineral deposits were formed in several cycles. He recognizes, as other geologists do for post Proterozoic time, the Caledonian, Hercinian, and Alpine geotectonic cycles. In this respect, he is an advocate of polycyclic development of folded provinces. However, his interpretation of which part of each cycle is involved in the formation of endogenic mineral deposits is fairly original. He regards the Caledonian metallogenic epoch as hardly productive under the Eurasian conditions; he associates all primary endogenic mineralization with the Hercinian epoch; and he regards endogenic ore deposits of the Alpine epoch as a result of marshalling up and redeposition of material of earlier-formed, chiefly Hercinian, ore deposits.

By the way, our own views on the G. Scheneiderchen concepts are known from our papers on regenerated deposits. As to the regard in which P. Ya. Antropov holds G. Schneiderchen, it has undergone an abrupt change in a short time. It was comparatively recently that he strongly supported the project of translating Schneiderchen's papers on regenerated ore deposits into Russian and it is largely thanks to him that this has been done. It is that much more surprising that he labels Schneiderchen's views on regenerated ore deposits as scholastic (pp. 7, etc.).

My own works, unlike Yu. A. Bilibin's, present a polycyclic development of folded provinces; unlike G. Schneiderchen, I believe that each cycle is represented by a primary mineralization of its own. I reject the possibility of the bulk of post-igneous mineral deposits having been formed solely in marshalling up the material of earlier ore deposits through its regeneration, as postulated by G. Schneiderchen. I believe that such redeposition, expressed in capturing material of more ancient deposits and its regeneration in subsequent mineralizations,

[1]Pis'mo v redaktsiyu (O kritike polozheniya v geologicheskoy nauke).

es place only in isolated and rather rare in-nces. This view is especially well presented the latest works of Academician A. P. Vino-adov (Geokhimiya, No. 7, 1959).

Thus, the difference in views on the forma-n and regularities of distribution of endogenic e deposits in the process of transformation of osynclinal systems to folded provinces, is te substantial between the three geologists.

Many statements in P. Ya. Antropov's article pear to be incorrect. It is erroneous, for ample, to deny any difference in igneous ac-ity and mineralization, between platforms d folded provinces. On the contrary, there a considerable difference in geologic struc-e and mineralization of the basements of pre-leozoic platforms and of post-Proterozoic geo-nclines. An even more radical difference is esent in metallogeny of geosynclinal and plat-rm stages of development throughout the reg-nal structure of the Soviet Union.

A peculiar aspect of P. Ya. Antropov's criti-sm must be mentioned.

First of all, he mounts, so to speak, a mas-ve criticism, taking in large groups of geo-gists at one swat. In his two most recent pap-s in Izvestiya of Schools of Higher Education, d in his Metallogenic and Exploration Maps, ma-Ata, 1959, he rejects the ideas of 13 stu-nts, not counting a large group of members the V. S. E. G. E. I.; the latter group he indicts a whole, without so much as mentioning any mes, as advocates of "a mechanistic view of e processes of development of geosynclinal stems." Such a totalitarian approach to the aluation of the works of our geologists cannot t cast some doubt on the validity of the criti-sm.

Second, in considering the views of various ologists, P. Ya. Antropov overtly abuses such ecific terms as "mechanistic approach," dealistic view," "eclectic and pseudo-scien-ic paths," "adventurous caper," "anti-scien-ic and scholastic ideas," etc. An excessive d inappropriate use of such figures of speech hardly conducive to a more convincing scien-ic argumentation and to a true criticism of e status of Soviet geologic science.

Third, P. Ya. Antropov, having rejected all the modern metallogenic concepts, fails to vance any new scientific hypothesis. Such ing the case, all his statements are negative. is quite obvious that such exclusively destruc-e criticism will remain ineffective until some-ing new has been advanced to take the place of e rejected concepts. This is not the case. If at is not enough, P. Ya. Antropov believes that s long as there is no penetrating, comprehen-ve, and truly scientific analysis of material hand, and not until it is used as a basis for deterimining regularities in the evolution of an ore process and relationships in the formation and distribution of ore deposits with features of geologic structures of regions, should any general recommendations be advanced." (p. 12).

Unlike P. Ya. Antropov, we believe that geology has long since reached that mature stage when it becomes possible to discern those main features of natural regularities in the formation and distribution of minerals, which are essential in a deliberate, scientifically founded direction of geologic exploration. Therein lies the difference between ours and P. Ya. Antropov's interpretation of the present status of geologic science.

To be sure, the present status of both theoretical and applied geology calls for a thoughtful and careful consideration of many fundamental problems, directed to eliminate shortcomings in further progress in this field of knowledge. Still, articles like the one published in Izvestya of School of Higher Learning is hardly to be regarded as useful in the improvement of geologic science and its practical significance.

A REVIEW OF "THEORY OF SEDIMENTARY ROCKS"[1, 2]

by

A. D. Sultanov, A. N. Solovkin, A. G. Seidov, and D. M. Suleymanov

This book is a general work on the petrography of sedimentary rocks. It contains a total of 572 pages, and consists of twenty chapters, a bibliography of 609 items, and is illustrated with 135 figures. With the exception of sections on experimental methods, the book reflects the status of knowledge of sedimentary rocks as of today.

Chapter One reviews briefly the mains stages and the direction of development of sedimentary petrography in the U. S. S. R., as well as the problems confronting it, along with brief data on the role of foreign scientists in the development of lithology.

Chapter Two contains definitions of principal sedimentary rocks, their classification, and considers their main stages of development. The problems of genesis, diagenesis, catagenesis, and hypergenesis are quite adequately treated, as are syngenesis and epigenesis. Of interest is the treatment of features of diagnesis at the lower boundary of its zone.

---

[1] O knige G. I. Teodorovicha "Ucheniye ob osadochnykh porodakh."

[2] Gostoptekhizdat, 1958.

Chapter Three is devoted to geologic facies, the evolution of this concept, the different orders of facies, the relation between facies and formations, the migration of facies, and their distribution depending on the nature of a basin and climate. The author rightly believes that a geologic facies, in its broad interpretation, encompasses all varieties of sedimentation. However, such facies are usually designated by petrographic and paleontologic criteria, i. e., they express mostly a sedimentary environment the sediment genosis; but geochemical or more precisely mineralogic facies are designated chiefly by their diagenetic features. This interpretation of geochemical facies makes possible their practical application, along with conventional geologic facies.

Chapter Four presents classifications of geochemical or mineralogic facies. The main concepts of geochemical facies, based on the analysis of parageneses for syngenetic sedimentary minerals, have been worked out by the author himself, to a considerable extent, and are of great importance in determining regularities in the distribution of various industrial sedimentary rocks.

Considered in Chapter Five are authigenie minerals of sedimentary deposits, as indexes of the physical and chemical environment in diagenesis of a sediment, in epigenesis of rocks, and in incipient metamorphism. The interesting material of this chapter is discussed too briefly; the chapter itself possibly should have been placed before that on geochemical facies.

The extensive Chapter Six treats structures, textures, the structural features of sedimentary beds, and the thicknesses of sedimentary rocks, as well as of bedding surfaces. This chapter is well written. The author is justified in recommending care in a genetic interpretation of various morphologic forms of cross-bedding. The description of various structures, such as cone-in-cone and suture-stylolite surfaces, as well as of the stages of their development, is original and erudite. It must be noted, however, that the last division of this chapter is too long.

Chapter Seven takes up weathering, transportation of material, and its deposition. The author emphasizes that mechanical and chemical differentiation of matter are more common as a simultaneous action rather than separately.

Chapter Eight describes unconsolidated and cemented clastic rocks, with arenaceous rocks discussed in particular detail. A detailed classification of sandstones, original with the author is given. This classification is unique in that it provides a logical differentiation for most diversified arenaceous rocks likely to be encountered in the particularly large scope of modern geologic exploration. Also considered is the relationship between terrigenous-mineralogic provinces and facies, a topic usually not discussed in lithologic literature.

The chapter on argillaceous rocks, (Chapter Nine) is too brief. Specifically, there is no discussion of recomputations of chemical composition of clays (of their 0.001 mm. facies) for structural formulas; only the computing procedure for oxides is given. This chapter gives a general idea of argillaceous rocks, their mineral and chemical composition, structure and texture, geochemical conditions of their formation, and their physical properties, along with the three principal types of argillaceous rocks. Many of the sections should have been illustrated with photographs. There are no data on the origin of clay minerals.

Chapter Ten (carbonate rocks) is well written and well illustrated. Of interest is the approach, a correct one in our opinion, to the controversial problem of sedimentary dolemite in the last section.

Chapter Eleven, on halogens, although short, is well written and raises no objections. Especially well presented are the conditions of transition from gypsum and anhydrite and vice versa.

Chapter Twelve, on siliceous rocks, gives their classification as well as that for argillaceous-carbonite-siliceous rocks, both original with the author and for the time being the only ones of the kind. Principles of a rational nomenclature for siliceous rocks and of efficient laboratory methods of their study are presented.

Chapters Thirteen and Fourteen deal with coal-bearing formations, the petrographic components of coals, their classification, stages of carbonization and metamorphism of coals, and their accumulation conditions. These chapters are interesting, written on the basis of new data (of N. M. Karavayev and others) and with the idea of bringing out the relation of coals (their types and degree of metamorphism) to oil shale and petroleum. The problem of a cyclic structure of most coal measures and of the lack of such structure in a number of instances is very objectively treated.

Chapter Fifteen, on natural gases and gas generating rocks, is short, carries general information, and ends in a discussion of gas and oil and gas provinces, basins, and zones, considered by geologic system. This chapter could have been quite harmlessly eliminated.

Oil source formations (Chapter Sixteen) are considered historically, then in the light of the results of a number of new studies of oil-producing rocks. Discussed are dispersion bituminous formations and the depth of subsidence necessary for the formation of industrial oil accumulations. The main problems in the study

oil producing rocks are set forth. This chap-
: is written on a high scientific level and
ens up new fields of study.

Chapter Seventeen describes the reservoir
cks, oil, natural gas, and water. Quite cor-
ctly, great importance is attributed to the
aluation of reservoir properties, their perme-
ility, and especially the structure of pore
ace as well as the relationship between perme-
ility and pore space structure. It should be
ted, however, that fracture reservoirs are
tlined too briefly.

Phosphate, bauxite, ferruginous and manga-
se sedimentary rocks are described in Chap-
r Eighteen. A classification of phosphates is
ven by their impurities and by mineral com-
sition. The author agrees with the basic pre-
ises of A.V. Kazakov's theory of a chemical
igin of phosphates. In his opinion, N.S. Shat-
iy's conclusions on the formation conditions
platform phosphates are acceptable, while
e latter's treatment of geosynclinal phosphates
e unequivocally "due to submarine volcanism"
e still subject to discussion.

Bauxites are described in terms of mineral
mposition, structure, chemical composition
$l_2O_3SiO_2$ ratio,) and origin. Genesis may be
fferent in different cases, and generally con-
oversial.

The section on sedimentary iron ores is com-
ete and raises no objections. Sedimentary
anganese ores are discussed very briefly but
th consideration given to facies aspects of
dimentation, to geotectonic, and to some ex-
nt to extensive-sedimentary processes.

Deposits of sedimentary nonferrous metals (Chapter Nineteen)are discussed for copper and lead and zinc ores, with a brief description of their mineral composition and the formation conditions. The sedimentary origin of many copper ores is beyond any doubt, and a probable sedimentary origin is suggested for a number of lead and zinc deposits.

The book ends with a chapter on general regularities in the formation of sedimentary rocks and industrial minerals. The author rightly emphasizes the major role of diagenesis of sediments and its significance in sedimentary mineralization, as well as the importance of epigenesis. In sharing the latest views of L.V. Pustovalov, he rightly believes that only the deposits of such relatively slightly mobile elements as iron, aluminum, and managanese may originate as the result of direct sedimentary chemical differentiation. The remaining sedimentary ore deposits of nonferrous and rare minerals (copper, lead, zinc, etc.) originate at an epigenetic stage, in the circulation of ground water through already-formed rocks, specifically in traps of some sort.

It should be noted that the text contains many errata and obscurities, omitted for some reason from the list of corrections. Some of the microphotographs are poorly printed. This, however, is the publishing house's fault.

On the whole, G.I. Teodorovich's Theory of Sedimentary Rocks is a valuable contribution to domestic scientific literature. It will play a useful part in the training of a corps of lithologists and it will be of great help to practical workers in various branches of geology.

BIBLIOGRAPHY

LITERATURE ON GEOLOGY
AND RELATED DISCIPLINES
RECEIVED AT THE LIBRARY OF THE
GEOLOGIC-GEOGRAPHIC SCIENCES BRANCH
OF THE USSR ACADEMY OF SCIENCES
IN OCTOBER 1959

A. Articles in Periodicals

GEOLOGY

1. Alabin, L.V., Ol'ginskiy intruzivnyy massiv na severo-zapade Kuznetskogo Alatau [THE OL'GA INTRUSIVE MASSIF IN THE NORTHWESTERN PART OF THE KUZNETSKIY ALATAU]: Vestn. Zap.-Sib. i Novosib. geol. upr., no. 3.

2. Babakhodzhayev, S.M., K voprosu o vozraste magmaticheskikh kompleksov basseynov rek Obi-Safed i Ios (yuzhnyy sklon Gissarskogo khrebta) [CONCERNING THE PROBLEM OF THE AGE OF THE IGNEOUS COMPLEXES IN THE BASINS OF THE OB'-SAFED AND IOS RIVERS (IN THE SOUTHERN SLOPES IN THE GISSAR RANGE)]: Zap. Tadz. otd. Vses. min. o-va, vyp. 1.

3. Baranova, N.M., S.T. Borisenko and V. Kh. Gevork'yan, Mezokaynozoyskiye otlozheniya zony Manuil'skogo razloma [THE MESOZOIC AND CENOZOIC DEPOSITS IN THE MANUIL'SKIY FAULT ZONE]: Geol. zh., Akademiya Nauk SSSR, t. 19, vyp 4.

4. Barkhatov, B.P., O pospeshnykh vyvodakh po stratigrafii nizhnego paleozoya Pamira [SOME HASTY CONCLUSIONS REGARDING THE STRATIGRAPHY OF THE LOWER PALEOZOIC IN THE PAMIR]: Izv., Akademiya Nauk TadzhSSR otd. yest. nauk. vyp. 1 (28).

5. Bashenina, N.V., Ponyatiye "tip rel'yefa" i klassifikatsiya tipov rel'yefa lednikovykh i vodno-lednikovykh akkumulyativnykh ravnin [THE CONCEPT OF "TYPE RELIEF" AND THE CLASSIFICATION OF RELIEF TYPES IN GLACIAL AND FLUVIOGLACIAL AGGRADATION PLAINS]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

6. Bernshteyn, V.A., O velichine napryazheniy, razvivayemykh knovektsiyey v obolochke na granitse yeye s zemnoy koroy [THE MAGNITUDE OF THE STRESSES DEVELOPED BY CONVECTION IN THE MANTLE AT THE BORDER OF THE EARTH'S CRUST]: Izv., Akademiya Nauk SSSR, ser. geofiz., no. 9.

7. Bondarchuk, V.G., P.K. Zamoriy and I.L. Sokolovskiy, Dvizheniya zemnoy kory na territorii USSR i MSSR posle al'piyskogo orogeneza [CRUSTAL MOVEMENTS WITHIN THE UKRAINIAN AND MOLDAVIAN SSRS AFTER THE ALPINE OROGENESIS]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

8. Bordunov, I.N., Novyye dannyye o saksaganskoy serii porod v Kremenchugskom rayone [NEW DATA ON THE SAKSAGAN ROCK SEQUENCE IN THE KREMENCHUG DISTRICT]: Dopovidi, Akademiya Nauk, USSR, no. 9.

9. Budanov, V.I., A.M. Meskhi, A.I. Proskurko and I.M. Derzhavets, K geologii intruziy vostochnoy chasti Pamirskogo khrebta [ON THE GEOLOGY OF THE INTRUSIVES IN THE EASTERN PART OF THE PAMIR RANGE]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

10. Bukatchuk, P.D., K voprosu stratigrafii i izuchennosti triasovykh otlozheniy Severo-Bukovinskikh Karpat [ON THE STRATIGRAPHY AND THE STUDY OF THE TRIASSIC DEPOSITS OF THE NORTHERN BUKOVINA CARPATHIANS]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

11. Banyushin, S.S., Mesto dayechnogo kompleksa Kafanskogo rudnogo rayona Armyanskoy SSR v tektonomagmaticheskoy

istorii razvitiya Somkhetsko-Karabakhskoy geosinklinali [THE PLACE OF THE DIKE COMPLEX OF THE KAFAN ORE DISTRICT OF THE ARMENIAN SSR IN THE TECTONIC AND MAGMATIC HISTORY OF THE SOMKHET-KARABAKH GEOSYNCLINE]: Dokl., Akademiya Nauk ArmSSR, t. 29, no. 2.

. Bakhromeyev, I.S., Geologicheskoye stroyeniye i etapy obrazovaniya Angashanskogo rudonosnogo massiva gabbro-anortozitov [THE GEOLOGIC STRUCTURE AND THE STAGES IN THE FORMATION OF THE ANGASHAN GABBRO-ANORTHOSITE ORE-BEARING MASSIF]: Vestn. vost.-sib. pravl., Chita, vyp. 1.

. Volin, A.V., Gravitatsionnyy tektogenez i tektonika istecheniya (obzor zarubezhnoy literatury) [GRAVITATIONAL TECTOGENESIS AND FLOW TECTONICS (A REVIEW OF FOREIGN LITERATURE)]: Sov. geol., no. 8.

. Volodarskiy, R.F., Istolkovaniye anomaliy sily tyazhesti vostochnykh rayonov Russkoy platformy v svete sovremennykh geologicheskikh i geofizicheskikh dannykh [AN INTERPRETATION OF THE GRAVITATIONAL ANOMALIES IN THE EASTERN PARTS OF THE RUSSIAN PLATFORM IN THE LIGHT OF CURRENT GEOLOGIC AND GEOPHYSICAL DATA]: Nauch. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

. Vysotskiy, B.P. and V.V. Tikhomirov, O deyatel'nosti Komissii po geologicheskoy izuchennosti SSSR (KOGI) za 1958 god [THE ACTIVITIES OF THE COMMITTEE FOR THE GEOLOGIC STUDY OF THE USSR (KOGI) FOR 1958]: Sov. geol., no. 8.

. Vyalov, O.S., K voprosu ob izmenenii skhemy stratigrafii miotsena Zakarpat'ya [CONCERNING THE CHANGES IN THE STRATIGRAPHIC SCHEME OF THE MIOCENE SERIES OF TRANSCARPATHIA]: Dopovidi, Akademiya Nauk, USSR, no. 9.

. Glebovskiy, Yu. S., Geologicheskiye stroyeniye rayona observatorii Mirnyy [THE GEOLOGIC STRUCTURE OF THE AREA OF THE MIRNYY OBSERVATION STATION]: Inform. byul. Sov. Antarkt. eksp., no. 8.

. Glebovskiy, Yu.S., Podlednyy khrebet v rayone stantsii Pionerskoy [A SUBGLACIAL RANGE IN THE VICINITY OF THE PIONERSKAYA STATION]: Inform. byul. Sov. Antarkt. eksp. no. 7.

. Goretskaya, Ye.N. and P.G. Rysin, Nizhnekamennougol'naya intruzivnaya faza y Yuzhnom Gissare na primere Khanakinskoy intruzii plagiogranitov [THE LOWER CARBONIFEROUS INTRUSIVE PHASE IN THE SOUTHERN GISSAR, FROM THE EXAMPLE OF THE KHANAKA PLAGIOGRANITE INTRUSIVES]: Zap. Tadzh., otd. Vses. min. o-va, vyp. 1.

20. Gorin, V.A., K voprosu o zemletryasenni v g. Baku 28 Noyabrya 1958 g. [THE EARTHQUAKE OF NOVEMBER 28, 1958 AT BAKU]: Dokl., Akademiya Nauk AzerbSSR, t. 15, no. 8.

21. Grichuk, M.P. and N.S. Sokolova, Novyye materialy o razvitii prirody yuzhnoy chasti o. Sakhalina v chetvertichnyy period [NEW MATERIALS ON THE DEVELOPMENT OF THE SOUTHERN PART OF THE ISLAND OF SAKHALIN IN THE QUATERNARY PERIOD]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

22. Daidbekova, E.A. and F.M. Kurbanova, Litofatsial'nyye osobennosti otlozheniy produktivnoy tolshchi Nizhne-Kurinskoy vpadiny v svyazi s ikh neftonosnost'yu [THE LITHOFACIES PROPERTIES OF THE DEPOSITS OF THE PRODUCING SERIES IN THE LOWER KURA BASIN, IN RELATION THEIR OIL CONTENT]: Azerb. neft. kh-vo, no. 8.

23. Dzhafarov, Kh.D., K voprosu geologicheskoy interpretatsii dannykh gravirazvedki v Prikaspiysko-Kubinskom rayone Azerbaydzhanskoy SSR [THE GEOLOGIC INTERPRETATION OF GRAVIMETRIC SURVEY DATA IN THE CASPIAN-KUBA REGION OF THE AZERBAYDZHAN SSR]: Izv. vyssh. uchebn. zaved., ser neft' i gaz, no. 10.

24. Dzhafarov, Kh.D., K tektonike Prikaspiysko-Kubinskoy neftenosnoy oblasti [THE TECTONICS OF THE CASPIAN-KUBA OIL-BEARING REGION]: Azerb. neft. kh-vo, no. 8.

25. Dyukov, A.I., Vsesoyuznaya geofizicheskaya konferentsiya [THE ALL-UNION GEOPHYSICAL CONFERENCE]: Sov. geol., no. 8.

26. Zhabin, A.G., O novom tipe karbonatitovykh proyavleniy v svyazi so shchelochnym kompleksom Vishnevykh-Il'menskikh gor na Urale [A NEW TYPE OF CARBONATITE OCCURRENCE ASSOCIATED WITH THE ALKALINE ROCK COMPLEX OF THE VISHNEV-IL'MEN MOUNTAINS IN THE URALS]: Dokl., Akademiya Nauk SSSR, t. 128, no. 5.

27. Zharkov, V.N., Termodinamika obolochki Zemli [THE THERMODYNAMICS OF THE EARTH'S MANTLE]: Izv., Akademiya Nauk SSSR, ser. geofiz., no. 9.

28. Zhuravlev, V.S. and R.A. Gafarov, Skhema tektoniki severo-vostoka Russkoy platformy [THE TECTONICS OF THE NORTHEASTERN PART OF THE RUSSIAN PLATFORM]: Dokl., Akademiya Nauk, SSSR, t. 128, no. 5.

29. Zhuravleva, I.T., L.N. Repina and V.V. Khomentovskiy, Nizhnekembriyskiye gorizonty Gornoy Shorii [THE LOWER CAMBRIAN STRATA OF THE GORNAYA SHORIYA]: Dokl., Akademiya Nauk SSSR, t. 128, no. 5.

30. Zonn, S.V., Razvitiye pochv na krasnotsvetnoy kore vyvetrivaniya [THE DEVELOPMENT OF SOILS ON A RED-COLORED WEATHERING CRUST]: Razv. i okhrana nedr, no. 9.

31. Zorin, L.V., O paleogeograficheskom znachenii merzlykh sloyev [THE PALEOGEOGRAPHIC SIGNIFICANCE OF FROZEN STRATA]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

32. Karavayev, M.N., Osnovnyye zakonomernosti v raspredelenii landshaftov Yakutin [THE BASIC LAWS GOVERNING THE DISTRIBUTION OF TOPOGRAPHIES IN YAKUTIYA]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

33. Kizeval'ter, D.S. and A.Yu. Rozanov, K voprosu o vozraste srednepaleozoyskikh izvestnyakov tsentral'noy chasti Severnogo Kavkaza [THE AGE OF THE MIDDLE PALEOZOIC LIMESTONES IN THE CENTRAL PART OF THE NORTHERN CAUCASUS]: Dokl., Akademiya Nauk SSSR, t. 128, no. 5.

34. Klushin, I.G., Issledovaniye raspredeleniya istochnikov gravitatsionnykh i magnitnykh anomaliy po glubine [A STUDY OF THE DISTRIBUTION IN DEPTH OF THE SOURCES OF GRAVITATIONAL AND MAGNETIC ANOMALIES]: Izv., Akademiya Nauk SSSR, ser. geofiz., no. 9.

35. Knyazev, G.I., O kontseptsii simmetrichnogo stroyeniya mezozoyskogo podvizhnogo poyasa Vostochnogo Zabaykal'ya [THE CONCEPTION OF THE SYMMETRICAL STRUCTURE OF THE MESOZOIC MOBILE ZONE OF THE EASTERN TRANSBAYKAL]: Vestn. Vost.-Sib. pravl., Chita, vyp. 1.

36. Kozhich-Zelenko, M.P. and V.A. Khomenko, Novoye litologicheskoye raschleneniye srednekamennougol'nykh otlozheniy Dneprovsko-Donetskoy vpadiny [A NEW LITHOLOGIC SUBDIVISION OF THE MIDDLE CARBONIFEROUS DEPOSITS OF THE DNEPR-DONETS BASIN]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

37. Kondorskaya, N.V. and G.A. Postolenko, Analiz nablyudeniy nad zemletryaseniyami Kurilo-Kamchatskoy oblasti [AN ANALYSIS OF EARTHQUAKE RECORDS IN THE KURILE-KAMCHATKA REGION]: Izv., Akademiya Nauk SSSR, ser. geofiz., no. 10.

38. Kononov, A.N., Stratigrafiya devonskikh obrazovaniy tsentral'noy chasti Anuysko-Chuyskogo sinklinoriya [THE STRATIGRAPHY OF THE DEVONIAN FORMATIONS IN THE CENTRAL PART OF THE AMUY-CHUY SYNCLINORIUM]: Vestn. Zap.-Sib. i Novosib. geol. upr., no. 3.

39. Kravchenko, S.M. and Ye.V. Vlasova, O redkometal'noy mineralizatsii, svyazannoy s nefelinovymi siyenitami shchelochnoy provintsii Tsentral'nogo Aldana [ON THE RARE-METAL MINERALIZATION ASSOCIATED WITH THE NEPHELINE SYENITES OF THE ALKALINE PROVINCE OF THE CENTRAL ALDAN]: Dokl. Akademiya Nauk SSSR, t. 128, no. 5.

40. Krivenkov, A.M. and G.I. Amurskiy, Pervoye respublikanskoye soveshcheniye po izucheniyu chetvertichnogo perioda Tadzhikskoy SSR [THE FIRST ALL-REPUBLIC MEETING ON THE STUDY OF THE QUATERNARY PERIOD IN THE TADZHIK SSR]: Izv., Akademiya Nauk TurkmSSR, no. 4.

41. Krivenkov, A.M. and N.A. Naginskiy, Pervoye respublikanskoye soveshcheniye po izucheniyu chetvertichnogo perioda Turkmenskoy SSR [THE FIRST ALL-REPUBLIC MEETING ON THE STUDY OF THE QUATERNARY PERIOD IN THE TURKMEN SSR]: Izv., Akademiya Nauk TurkmSSR, no. 4.

42. Kuznetsov, V.P., Zemletryaseniye v Baku 28 Noyabrya 1958 g. [THE EARTHQUAKE OF NOVEMBER 28, 1958 AT BAKU]: Dokl., Akademiya Nauk AzerbSSR, t. 15, no. 8.

43. Kurbanov, M. and R.D. Nepesov, K voprosu o svyazi magnitnykh i gravitatsionnykh anomaliy s seysmichnost'yu i sovremennymi dvizheniyami na territorii Turkmenistana [THE PROBLEM OF THE RELATIONSHIP OF MAGNETIC AND GRAVITATIONAL ANOMALIES TO THE SEISMIC ACTIVITY AND PRESENT

MOVEMENTS IN THE TERRITORY OF TURKMENISTAN]: Izv., Akademiya Nauk TurkmSSR, no. 4.

4. Kukhtikov, M.M., V.D. Saltovskaya, and I.N. Cherenkov, Novyye dannyye o kamennougol'nykh otlozheniyakh i geologicheskom stroyenii Yuzhnogo sklona gor Chumkar-Tau (Zapadnaya okonechnost' Turkestanskogo khrebta) [NEW DATA ON THE CARBONIFEROUS DEPOSITS AND GEOLOGIC STRUCTURE OF THE SOUTHERN SLOPES OF THE CHUMKAR-TAU MOUNTAINS (THE WESTERN END OF THE TURKSTAN RANGE)]: Zap. Tadzh. otd. Vses. min. o-va, vyp 1.

5. Lazarev, V.S. and A.G. Kobilev, O tipomorfizme porod uglenosnoy tolshchi Donbassa i zakonomernostyakh v naplastovanii tipomorfnykh raznostey v razrezakh [ON THE TYPOMORPHISM OF THE ROCKS IN THE COAL-BEARING SERIES OF THE DONETS BASIN AND THE LAWS CHARACTERIZING THE LAYERING OF THE TYPOMORPHIC VARIETIES IN THE SECTIONS]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 4.

6. Larin, V.I., Novyye dannyye po geologii yuzhnoy chasti Stepnogo Mangyshlaka [NEW DATA ON THE GEOLOGY OF THE SOUTHERN PART OF THE STEPNOY MANGYSHLAK]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

7. Lebedev, V.G., Rol' noveyshikh tektonicheskikh dvizheniy v formirovanii rel'yefa plato Shan'si [THE ROLE OF RECENT TECTONIC MOVEMENTS IN THE FORMATION OF THE RELIEF OF THE SHAN'SI PLATEAU]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

8. Lebedinskiy, V.I. and T.I. Dobrovol'skaya, Novyye dannyye o kristalicheskom fundamente Prichernomorskoy vpadiny [NEW DATA ON THE CRYSTALLINE BASEMENT OF THE BLACK SEA BASIN]: Sov. geol., no. 8.

9. Leven, E.Ya., K voprosu o vozraste murgabskoy svity na Vostochnom Pamire [THE AGE OF THE MURGAD SUITE IN THE EASTERN PAMIR]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

0. Lichkov, B.L., Uchenyy i isledovatel'. Yubiley [B.L. LICHKOV — SCIENTIST AND RESEARCHER]: Izv., Akademiya Nauk TadzhSSR, otd. yest. nauk, vyp. 1 (28).

1. Lotiyev, B.K., O nekotorykh osobennostyakh tektoniki Peredovykh khrebtov [SOME SPECIAL FEATURES OF THE TECTONICS OF FRONT RANGES]: Izv. vyssh. uchebn. zaved., ser. neft' i gaz, no. 10.

52. Makarova, Z.V., Polozheniye polyusa v triase po ostatochnoy namagnichennosti bazal'tovykh trappov Yeniseya [THE POSITION OF THE MAGNETIC POLE DURING THE TRIASSIC, BASED ON THE RESIDUAL MAGNETIZATION OF THE YENISEY BASALT TRAPS]: Izv. Akademiya Nauk SSSR, ser. geofiz., no. 10.

53. Markhinin, Ye.K. and G.A. Pospelova, Nekotoryye dannyye paleomagnitnykh issledovaniy na Kuril'skikh ostrovakh [SOME INFORMATION ON THE PALEOMAGNETIC INVESTIGATIONS OF THE KURILE ISLANDS]: Izv., Akademiya Nauk SSSR, ser. geofiz., no. 10.

54. Miklukho-Maklay, A.D. and Yu.P. Yershov, Ob ustanovlenii verkhnepermskikh morskikh otlozheniy v Koryakskom khrebte [ON THE IDENTIFICATION OF UPPER PERMIAN MARINE DEPOSITS IN THE KORYAK RANGE]: Dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

55. Nesmeyanov, S.A., O raschlenenii permskikh otlozheniy Tenizskoy vpadiny [THE SUBDIVISION OF THE PERMIAN DEPOSITS OF THE TENIZ BASIN]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

56. Nesterov, L.Ya., Nekrolog [L.YA. NESTEROV, OBITUARY]: Sov. geol. no. 8.

57. Neutriyevskaya, N.V., Novyye dannyye o geologicheskom stroyenii severnoy chasti Tersinskogo rayona [NEW DATA ON THE GEOLOGIC STRUCTURE OF THE NORTHERN PART OF THE TERSA REGION]: Vestn. Zap.-Sib. i Novosib. geol. upr., no. 3.

58. Nikiforov, L.G., Nekotoryye osobennosti dinamiki beregovoy zony Krasnovodskogo poluostrova [SOME FEATURES OF THE DYNAMICS OF THE LITTORAL ZONE OF THE KRASNOVODSK PENINSULA]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

59. Panov, D.G., O drevnosti Tikhogo okeana [ON THE ANTIQUITY OF THE PACIFIC OCEAN]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

60. Petkevich, G.I., O nekotorykh zakonomernostyakh izmeneniya skorostey rasprostraneniya uprugikh voln v Predkarpatskom progibe [SOME LAWS GOVERNING THE CHANGES IN THE DISTRIBUTION VELOCITY OF ELASTIC WAVES IN THE

CISCARPATHIAN BASIN]: Dopovidi, Akademiya Nauk URSR, no. 9.

61. Proskurko, A.I., Nekotoryye voprosy geologii i geomorfologii rayona Usoyskogo zavala [SOME PROBLEMS OF THE GEOLOGY AND GEOMORPHOLOGY OF THE AREA OF THE USOY ARCH]: Izv., Akademiya Nauk TadzhSSR, otd. yest. nauk, vyp. 1 (28).

62. Rodygin, A.I., O vozraste Aksayskoy effuzivno-osadochnoy svity Saylyugemskogo khrebta [ON THE AGE OF THE AKSAY EXTRUSIVE-SEDIMENTARY SUITE OF THE SAYLYUGEN RANGE]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

63. Ryzhkov, O.A., K kharakteristike al'piyskoy tektoniki antiklinal'nykh podnyatiy yugo-zapadnykh Kyzylkumov [SOME FEATURES OF THE ALPINE TECTONICS OF THE ANTICLINAL UPLIFTS IN THE SOUTHWESTERN KYZYLKUMY]: Dokl., Akademiya Nauk UzSSR, no. 9.

64. Savarenskiy, Ye.F. and Sh.S. Ragimov, Ob opredelenii sredney tolshchiny zemnoy kory po gruppovym skorostyam voln Releya [THE DETERMINATION OF THE AVERAGE THICKNESS OF THE EARTH'S CRUST FROM THE GROUP VELOCITIES OF RAYLEIGH WAVES]: Izv., Akademiya Nauk SSSR, ser. geofiz. no. 9.

65. Sevryugin, N.A., Geologicheskoye stroyeniye Prisemipalatinskogo rayona [THE GEOLOGIC STRUCTURE OF THE SEMIPALATINSK REGION]: Sov. geol. no. 8.

66. Simonov, Yu.G., K voprosu o proiskhozhdenii pologikh sklonov v nizhnem i srednem Priangar'ye [ON THE ORIGIN OF THE GENTLE SLOPES IN THE LOWER AND MIDDLE ANGARA REGION]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

67. Sokolovs'kiy, I.L., Naynovishi ta suchasni rukhi zemnoï kori na teritoriï URSR [RECENT AND EARLY CRUSTAL MOVEMENTS IN THE TERRITORY OF THE UKRAINIAN SSR]: Visn. Akademiya Nauk USSR, no. 9.

68. Sizhuk, A.G., Literatura po geologii, geomokfologii i gidrogeologii Tadzhikistana (1951-1955) [THE LITERATURE ON THE GEOLOGY, GEOMORPHOLOGY AND HYDROGEOLOGY OF TADZHIKSTAN (1951-1955)]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

69. Solov'yev, S.L., Sessiya po seysmichnosti v tektonike Pribaykal'ya i smezhny territoriy [THE CONFERENCE ON THE SEISMIC ACTIVITY AND TECTONICS OF THE PRIBAYKAL'YE AREA AND ADJOINING TERRITORIES]: Izv. Akademiya Nauk SSSR, ser. geofiz., no. 10.

70. Sytinskiy, A.D., Karta raspredeleniya epitsentrov zemletryaseniy po nablyudeniyam v observatorii Mirnyy [A MAP SHOWING THE DISTRIBUTION OF EARTHQUAKE EPICENTERS, BASED ON OBSERVATIONS MADE AT THE MIRNYY OBSERVATION STATION (IN ANTARCTICA)]: Inform. byul. Sov. Antarkt. eksp., no. 7.

71. Syabryay, V.T., Otvet na stat'yu V.V. Kiryukova "Po povodu raboty V.T. Syabryaya" Genezis burogo uglya Dnepro skogo basseyna" [AN ANSWER TO V.V. KIRYUKOV'S ARTICLE "ON THE SUBJECT OF V.T. SYABRYAY'S PAPER, "THE GENESIS OF THE BROWN COAL OF THE DNEPR BASIN"]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

72. Tel'ye, Ye. and Tel'ye, O., Ob intensivnosti magnitnogo polya Zemli v istoricheskom i geologicheskom proshlom [THE INTENSITY OF THE EARTH'S MAGNET FIELD IN THE HISTORICAL AND GEOLOGIC PAST]: Izv. Akademiya Nauk SSSR, ser. geofiz., no. 9.

73. Khodak, Yu.A. and Sun' Shu., Sopostavleniye drevnikh tolshch severo-vostoka Kitaya i yuga Sovetskogo Dal'nego Vostoka [A CORRELATION OF THE ANCIENT ROCKS IN THE NORTHEAST OF CHINA AND THE SOUTHERN PART OF THE SOVIET FAR EAST]: Dokl., Akademiya Nauk SSSR, t. 128, no. 5.

74. Tsepelev, N.S. and N. Bekmuradov, Chetvertoye vsesoyuznoye litologichesk soveshchaniye [THE FOURTH ALL-UNION CONFERENCE ON LITHOLOGY]: Izv., Akademiya Nauk TurkmSSR, no. 4

75. Sharfman, V.S., Stratigrafiya i tektonika zelenokamennogo sinklinoriya Baymakskogo rayona Bashkirii [THE STRATIGRAPHY AND TECTONICS OF THE GREENSTONE SYNCLINORIUM OF THE BAYMAK AREA OF BASHKIRIYA]: Sov. geol., no. 8.

76. Shneyerson, B.L., O prichinakh intensiv nykh magnitnykh anomaliy KMA [ON TH CAUSES OF INTENSIVE KMA MAGNETI ANOMALIES]: Izv., Akademiya Nauk SSSR, ser. geofiz., no. 10.

7. Enenshteyn, B.S., O.A. Skugarevskaya and Ye.V. Rybakova, Nekotoryye dannyye o zondirovaniyakh metodom stanovleniya elektricheskogo toka v Zemle [SOME DATA ON SOUNDINGS MADE BY THE METHOD OF INDUCING AN ELECTRICAL CURRENT IN THE EARTH]: Izv., Akademiya Nauk SSSR, ser. geofiz., no. 10.

PALEONTOLOGY

8. Bagdasaryan, K.G., K voprosu ob izuchenii mollyuskovoy fauny chorkakskogo gorizonta Gruzii [THE STUDY OF THE MOLLUSCAN FAUNA OF THE CHOKRAK STRATUM IN GEORGIA]: Dokl., Akademiya Nauk SSSR, t. 128, no. 5.

9. Balabay, P.P., O faune pteraspod Podol'skoy plity [THE PTERASPOD FAUNA OF THE PODOLIAN SHIELD]: Geol. zh., Akademiya Nauk USSR, t. 19., vyp. 4.

0. Bogachev, V.V., Zamechaniya na robotu L.A. Nevesskoy "Chetvertichnyye morskiye mollyuski Turkmenii" [SOME REMARKS ON L.A. NEVESSKAYA'S PAPER, "THE QUATERNARY MARINE MOLLUSCS OF TURKMENIA"]: Izv., Akademiya Nauk TurkmSSR, no. 4.

1. Lavrusevich, A.I., Novyy rod chavsiakia iz ludlovskikh otlozheniy Zeravshano-Gissarskoy oblasti [A NEW GENUS, CHAVSAKIA, FROM THE LUDLOVIAN DEPOSITS OF THE ZERAVSHAN-GISSAR REGION]: Izv., Akademiya Nauk TadzhSSR, otd. yest. nauk, vyp. 1 (28).

2. Leleshus, V.L., Ob odnom iz napravleniy izmenchivosti roda Multisolenia Fritz [ONE OF THE TENDENCIES IN THE VARIABILITY OF THE GENUS MULTISOLENIA FRITZ]: Izv., Akademiya Nauk TadzhSSR, otd. yest. nauk, vyp. 1 (28).

3. Pospelov, A.G., Rezul'taty rabot ZSGU po paleontologii i stratigrafii v 1958 g. [THE RESULTS OF THE WORK ON PALEONTOLOGY AND STRATIGRAPHY IN 1958 AT THE STATE UNIVERSITY OF WESTERN SIBERIA]: Vestn., Zap.-Sib. i Novosib. geol. upr., no. 3.

4. Reyman, V.M., Nekotoryye osobennosti morfologii chetyrekhluchevykh korallov [SOME SPECIAL FEATURES OF THE MORPHOLOGY OF TETRACORALS]: Izv., Akademiya Nauk TadzhSSR, otd., yest. nauk, vyp. 1 (28).

5. Romodanova, A.P., and A.I. Shevchenko, Novaya nakhodka ostatkov iskopayemykh mlekopitayushchikh srednepleystotsenovogo vozrasta na Ukraine [A NEW DISCOVERY OF FOSSIL MAMMAL REMAINS OF MIDDLE PLEISTOCENE AGE IN THE UKRAINE]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

PETROGRAPHY, MINERALOGY, CRYSTALLOGRAPHY AND GEOCHEMISTRY

86. Allakhverdiyev, Sh.I., Kerolity v produktakh vyvetrivaniya serpentinitov Malogo Kavkaza [CEROLITES IN THE WEATHERING PRODUCTS OF THE SERPENTINITES IN THE LESSER CAUCASUS]: Dokl., Akademiya Nauk AzerbSSR, t. 15 no. 8.

87. Alyavdin, V.F., O spravochnykh rukovodstvakh po mineralogii [REFERENCE MANUALS ON MINERALOGY]: Zap. Vses. min. o-va, ch. 88, vyp 5.

88. Ananyan, A.A., Vzaimodeystviye vody s gornoy porodoy v svete predstavleniy o strukture vody [THE REACTIONS BETWEEN WATER AND ROCK IN THE LIGHT OF THE CONCEPTS OF THE STRUCTURE OF WATER]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

89. Arbuzova, S.K., K mineralogii svintsovo-flyuoritovykh mestorozhdeniy Kondara i Diamalik [THE MINERALOGY OF THE KONDAR AND DIAMALIK LEAD-FLUORITE DEPOSITS]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

90. Bgatov, V.I., Rtutnyye proyavleniya na territorii g. Suchana [MERCURY OCCURRENCES IN THE SUCHAN AREA]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

91. Blokhina, N.A., Nekotoryye osobennosti parageniticheskikh sootnosheniy skarnov, okislov zheleza i sul'fidov na skarnovom mestorozhdenii Maykhura [SOME SPECIAL FEATURES OF THE PARAGENETIC RELATIONSHIPS BETWEEN THE SKARNS, IRON OXIDES AND SULFIDES IN THE MAYKHUR SKARN DEPOSIT]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

92. Buldakov, V.V., Osobennosti metasomaticheskikh izmeneniy granitov massiva Maytas [METASOMATIC ALTERATIONS OF THE GRANITES OF THE MAYTAS MASSIF]: Izv., vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

93. Burgelya, N.K., Pizolitovyy siderit iz Bakal'skogo mestorozhdeniya [A PISOLITIC SIDERITE FROM THE BAKAL' DEPOSIT]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

94. Varlakov, A.S., Montichellitovaya poroda iz Akhmatovskoy kopi [A MONTICELLITE ROCK FROM THE AKHMATOV PILE]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

95. Vinokurov, V.M., Magnitnyye svoystva mineralov gruppy vol'framita [THE MAGNETIC PROPERTIES OF THE MINERALS IN THE WOLFRAMITE GROUP]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

96. Vlasenko, A.V., Amfibolitovyye porody Il'menskikh gor [ON THE AMPHIBOLITE ROCKS OF THE IL'MEN MOUNTAINS]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

97. Gavrilov, F.F., Spektral'nyy metod izotopnogo analiza litiya [THE SPECTRUM METHOD OF ISOTOPE ANALYSIS FOR LITHIUM]; Optika i spektroskopiya, t. 7, vyp. 3.

98. Gendelev, S.Sh., Shtrikhovka rosta na kristallakh i yeye minerageneticheskoye znacheniye [THE GROWTH STRIATIONS ON CRYSTALS AND THEIR MINERALGENETIC SIGNIFICANCE]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

99. Grigor'yev, D.P., O skorosti kristallizatsii mineralov [THE RATE OF CRYSTALLIZATION OF MINERALS]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

100. Dayev, D.C., Ob obrabotke i istolkovanii dannykh radiovolnogo prosvechivaniya [ON THE TREATMENT AND INTERPRETATION OF DATA ON RADIO-WAVE TRANSLUCENCE]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

101. Danilova, A.D., O khantite iz Takfonskogo mestorozhdeniya [A KHANTITE FROM THE TAKFON DEPOSIT]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

102. Delitsin, I.S., Primer sovmestnogo proyavleniya opticheskoy oriyentirovki, sootvetstvuyushchey R-, B- and S-Tektonitam [AN EXAMPLE OF THE SIMULTANEOUS OCCURRENCE OF OPTICAL ORIENTATIONS CORRESPONDING TO THE R-, B-, AND S-TEKTONITES]: Sov. geol. no. 8.

103. Dibrov, V.Ye., O vzaimootnosheniyakh biotita i muskovita v Biryusinskikh pegmatitakh [THE RELATIONSHIPS BETWEEN THE BIOTITE AND MUSCOVITE IN THE BIRYUSA PEGMATITES]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

104. Yevzikova, N.Z., Zamechaniya k stat'ye V.F. Barabanova "Flyuorit iz Bukukinsko vol'framitovogo mestorozhdeniya (Vostochnoye Zabaykal'ye)" [SOME REMARKS ON V.F. BARABANOV'S ARTICLE, "FLUORITE FROM THE BUKUKA WOLFRAMITE DEPOSIT (EASTERN TRANSBAYKAL)"]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

105. Yermolayev, M.M., K geokhimii redkometal'nykh granitnykh pegmatitov [THE GEOCHEMISTRY OF RARE-METAL GRANITIC PEGMATITES]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

106. Zhdanov, V.V., Dve generatsii kianita v gneysakh Belomorskogo kompleksa [TWO GENERATIONS OF KYANITE IN THE GNEISSES OF THE WHITE SEA COMPLEX]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

107. Zheru, M.I., Magnezit v mramorakh mestorozhdeniya "Pereval" [A MAGNESITE IN THE MARBLES OF THE "PEREVAL" DEPOSIT]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

108. Zagibalov, Ya.N., Opyty po opredeleniyu soderzhaniya slyudy-syrtsa po kernovym probam v pegmatitovykh zhilakh [ATTEMPT TO DETERMINE THE CONTENT OF MICA RAW MATERIAL FROM CORE SAMPLES IN PEGMATITE VEINS]: Razv. i okhrana nedr, no. 9.

109. Zolotukhin, V.V., O kal'tsite i "zakonservirovannoy" vode iz olivinovykh datsitov Chernoy gory (Zakarpat'ye) [ON THE CALCITE AND THE "PRESERVED" WATER IN THE OLIVINE DACITES OF THE BLACK MOUNTAIN (TRANSCARPATHIA)]: Geol. zh. Akademiya Nauk USSR, t. 19, vyp, 4.

110. Ivkin, N.M., N.S., Kitaygorodskiy, D.D. Kotel'nikov and Yu.M. Korolev, Analog alevardita (iz Dagestana) [AN ANALOGUE OF ALEVARDITE (FROM DAGESTAN)]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

111. Ismailov, M.I., O ksonotlite iz Almalykskogo rudnogo polya [A XONOTLITE FROM THE ALAMALYK ORE FIELD]: Dokl. Akademiya Nauk UzSSR, no. 9.

112. Ishchenko, D.I., S.M. Ryabokon' and G.I. Struyeva, Apatit iz kvartsevoy zhily verkhey svity Krivogo Roga [APATITE FROM THE QUARTZ VEIN IN THE UPPER SUITE OF THE KRIVOY ROG REGION]: Geol. zh. Akademiya Nauk USSR, t. 19, vyp. 4.

113. Kabilov, Sh.K., Sferosiderity v uglyakh

Fan-Yagnobskogo mestorozhdeniya [SPHEROSIDERITES IN THE COALS OF THE FAN-YAGNOB DEPOSIT]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

4. Kagner, M.N., Sravnitel'naya otsenka dispernosti lentochnykh glin otdel'nykh rayonov Severo-Zapada RSFSR [A COMPARATIVE EVALUATION OF THE DISPERSION OF LENTICULAR CLAYS IN INDIVIDUAL DISTRICTS OF THE NORTHWEST OF THE RSFSR]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

5. Karasik, M.A., Osobennosti raspredeleniya elementov-primesey v kompleksnykh magnetitovykh rudakh nekotorykh kontaktovo-metasomaticheskikh mestorozhdeniy [THE DISTRIBUTION OF ADMIXTURE ELEMENTS IN THE COMPLEX MAGNETITE ORES OF CERTAIN CONTACT-METASOMATIC DEPOSITS]: Razv. i okhrana nedr, no. 9.

6. Kaurkovskiy, V.I., Termograficheskiye dannyye o geneticheskoy svyazi "Kraskovykh" rud s sideritami v Krivorozhskom basseyne [THERMOGRAPHIC DATA ON THE GENETIC CONNECTION BETWEEN THE "KRASKOV" ORES AND THE SIDERITES IN THE KRIVOY ROG BASIN]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

7. Klassen, V.I. and Mao Tszi-Fan', O mekhanizme deystviya zhidkogo stekla pri flotatssii nesul'fidnykh mineralov [ON THE MECHANISM OF THE ACTION OF LIQUID GLASS IN THE FLOTATION OF NON-SULFIDE MINERALS]: Tsvetn. metally, no. 9.

8. Klimanov, A.M., O raspredelenii glinistogo veshchestva v razlichnykh tipakh podmoskovnykh ugley [ON THE DISTRIBUTION OF CLAY MATTER IN VARIOUS TYPES OF MOSCOW BASIN COALS]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

9. Kononov, L.P., Sferosiderity v yurskikh otlozheniyakh Severnoy Fergany [SPHEROSIDERITES IN THE JURASSIC DEPOSITS OF THE NORTHERN FERGANA REGION]: Dokl., Akademiya Nauk UzSSR, no. 9.

0. Kuznetsov, Ye.A., Dispersionnyy metod analiza mineralov [THE DISPERSION METHOD OF MINERAL ANALYSIS]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

1. Kukovskiy, Ye.G. and Ye.K. Lazarenko, Verlit iz Zakarpat'ya [A WEHRLITE FROM TRANSCARPATHIA]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

122. Lukanina, M.I., Svanbergit v boksitakh Kamenskogo rayona na Srednem Urale [A SVANBERGITE IN THE BAUXITES OF THE KAMEN DISTRICT IN THE MIDDLE URALS]: Zap. Vses. min. o-va. ch. 88, vyp. 5.

123. Lyashkevich, Z.M., Ksenolity intruzivnykh porod v siyenitakh Turpi (Alayskiy khrebet) [XENOLITHS OF INTRUSIVE ROCKS IN THE TURPA SYENITES (THE ALAY RANGE)]: Izv., Akademiya Nauk TadzhSSR, otd. yest. nauk, vyp. 1 (28).

124. Makarochkin, B.A., K.A. Gonibesova and M.S. Makarochkina, Chevkinit iz Il'menskikh gor [CHEVKINITE FROM THE IL'MEN MOUNTAINS]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

125. Mamedov, Kh.S., O klassifikatsii silikatov [ON THE CLASSIFICATION OF SILICATES]: Dokl., Akademiya Nauk AzerbSSR, t. 15, no. 8.

126. Makhnach, A.S., Rezul'taty spektral'nykh analizov porod kristallicheskogo fundamenta i drevnego paleozoya Belorussii [THE RESULTS OF SPECTRUM ANALYSES OF THE ROCKS OF THE CRYSTALLINE BASEMENT AND THE ANCIENT PALEOZOIC ROCKS OF BELORUSSIA]: Dokl., Akademiya Nauk BSSR, t. 3, no. 7.

127. Nadiradze, V.R., Redkiye i rasseyannyye (malyye) elementy v magmaticheskikh porodakh i v rudakh endogennykh mestorozhdeniy Adzharo-Trialetii [RARE AND DISPERSED (MINOR) ELEMENTS IN THE IGNEOUS ROCKS AND ORES OF THE ENDOGENIC DEPOSITS OF THE ADZHARA-TRIALETY REGION]: Soobshch., Akademiya Nauk GruzSSR, t. 23, no. 1.

128. Nikitin, V.D., K diskussii o vliyanii vmeshchayushchikh gornykh porod na tip mineralizatsii endogennykh mestorozhdeniy [TOWARD A DISCUSSION OF THE EFFECT OF THE HOST ROCKS ON THE TYPE OF MINERALIZATION IN ENDOGENIC DEPOSITS]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

129. Novikova, T.I., Mineraly kaolinovoy gruppy Dzhizhikrutskogo rtutno-sur'myanogo mestorozhdeniya [MINERALS OF THE KAOLIN GROUP IN THE DZHIZHIKRUT MERCURY-ANTIMONY DEPOSIT]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

130. Nyrkov, A.A., Sulunit, —novyy mineral iz gruppy zhelezistykh khloritov [SULUNITE—A NEW MINERAL OF THE

FERRUGINOUS CHLORITES GROUP]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

131. Plesko, A.V., Nekotoryye dannyye o nakoplenii talliya v ugliyakh Tadzhikistana [SOME DATA ON THE ACCUMULATION OF THALLIUM IN THE COALS OF TADZHIKISTAN]: Izv., Akademiya Nauk TadzhSSR, otd. yest. nauk, vyp 1 (28).

132. Plesko, A.V., Talliysoderzhashchiye sul'fidnyye mineraly Tadzhikistana [THALLIUM-CONTAINING SULFIDE MINERALS OF TADZHIKISTAN]: Zap. Tadzh. otd. Vses. min. 0-va, vyp. 1.

133. Rafal'skiy, R.P. and K.F. Kudinova, Eksperimental'noye izucheniye usloviy vostanovleniya i osazhdeniya urana mineralami [AN EXPERIMENTAL STUDY OF THE CONDITIONS OF REDUCTION AND DEPOSITION OF URANIUM BY MINERALS]: Atomnaya energiya, t. 7, vyp 4.

134. Romanovich, I.F., Izmeneniye ob"yemov pri metasomatoze v svyazi s obrazovaniyem zalezhey malozhelezistogo tal'ka [VOLUME CHANGES IN METASOMATISM ASSOCIATED WITH THE FORMATION OF LOW-IRON TALC DEPOSITS]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

135. Samonov, I.Z., Nekotoryye osobennosti mineraloobrazovaniya v rudakh Belukhinskogo mestorozhdeniya i voprossy raspredeleniya vol'framita v zhil'nykh mestorozhdeniyakh [SOME SPECIAL FEATURES OF MINERAL FORMATION IN THE ORES OF THE BELUKHA DEPOSIT AND PROBLEMS OF THE DISTRIBUTION OF WOLFRAMITE IN VEIN DEPOSITS]: Izv. vyssh. uchebn. zaved. ser. geol. i razvedka, no. 6.

136. Serebryakov, V.A., Avtometasomaticheskoye izmeneniye granitoidov i priurochennosti' proyavleniy olovonosnosti k zone natrovo-kaliyevogo metasomatoza [THE AUTOMETASOMATIC ALTERATION OF GRANITOIDS AND THE ASSOCIATION OF TIN OCCURRENCES WITH ZONES OF SODIUM-POTASSIUM METASOMATISM]: Sov. geol. no. 8.

137. Siroshtan, R.I. and N.P. Polovko, Rogovyye obmanki metabazitov zhelezistokremnistykh formatsiy Ukrainskogo kristallicheskogo shchita [HORNBLENDES OF THE METABASITES OF THE IRON-SILICA FORMATIONS OF THE UKRAINIAN CRYSTALLINE SHIELD]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

138. Strygin, A.I., Paragenezis mineralov egirinizirovannykh porod krivorozhskoy serii [THE PARAGENESIS OF THE MINERALS IN THE AEGIRINIZED ROCKS OF THE KRIVOY ROG SERIES]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

139. Stulov, N.N. and I.I. Shafranovskiy, Novyye materialy k tvorcheskoy biografii Ye.S. Fedorova [NEW MATERIALS FOR A CREATIVE BIOGRAPHY OF YE.S. FEDOROV]: Zap. Vses. min. o-va, ch. 88, vyp 5.

140. Tikhomirov, S.V., O formi vyrazheniya zakona periodichnosti [ON THE FORM OF MANIFESTATION OF THE LAW OF PERIODICITY]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

141. Tikhonenkova, R.P., Ob amfibolakh in"yektsionno-kontaktovykh porod Talovskikh gor (Yu. Ural) [ON THE AMPHIBOLES OF THE INJECTION-CONTACT ROCKS IN THE TALOV MOUNTAINS (SOUTHERN URALS)]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

142. Filippov, Ye.M. and G.A. Kuznetsov, Opredeleniye plotnostey gornykh porod i rud v obnazheniyak i gornykh vyrabotak s pomoshch'yu metoda rasseyannogo gamma-izlucheniya [DETERMINATION OF THE DENSITIES OF ROCKS AND ORES IN OUTCROPS AND MINE WORKINGS BY THE DISPERSED GAMMA-RADIATION METHOD]: Razv. i okhrana nedr, no. 9.

143. Khamidov, M.Kh., Geneticheskiye tipy i osobennosti rasprostraneniya aktsesornykh mineralov v komplekse ranneal'pivskikh granitoidnykh porod Zapadnogo Pamira [THE GENETIC TYPES AND THE DISTRIBUTION OF ACCESSORY MINERALS IN THE COMPLEX OF EARLY ALPINE GRANITOID ROCKS OF THE WESTERN PAMIR]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

144. Chervyakovskiy, G.F. and A.V. Govorov, Biotitovyy monchikit iz Krasnoural'skogo rayona na Srednem Urale [A BIOTITE MONCHIQUITE FROM THE KRASNOURAL'SK DISTRICT IN THE MIDDLE URALS]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

145. Chesnokov, B.V., O lyuminestsentsii i vnutrennem stroyenii kristallov tsirkona iz Vishnevykh gor na Urale [THE LUMINESCENCE AND INTERNAL STRUCTURE OF ZIRCON CRYSTALS FROM THE VISHNEV MOUNTAINS IN THE URALS]: Zap. vses. min. o-va, ch. 88, vyp. 5.

46. Shokhina, O.I., Osobennosti sostava i stroyeniya shchelochnykh porod Bulan-Kul'skogo massiva [THE COMPOSITION AND STRUCTURE OF THE ALKALINE ROCKS OF THE BULAN-KUL' MASSIF]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

47. Shcherbak, M.P., O genezise granato-pirokseno-plagioklazovykh porod Zhitomirshchiny [ON THE GENESIS OF THE GARNET-PYROXENE-PLAGIOCLASE ROCKS OF ZHITOMIRSHCHINA]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

48. Epshteyn, G. Yu., O molibdatakh urana-moluranite i iriginite [ON THE URANIUM MOLYBDATES—MOLURANITE AND IRIGINITE]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

49. Yakshin, V.I., Izmeneniye okraski rutila v zavisimosti ot vneshney sredy [THE CHANGE IN THE COLOR OF RUTILE AS RELATED TO THE EXTERNAL MEDIUM]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

50. Yanulov, K.P., K voprosu o soderzhanii ponyatiya izomorfizm [ON THE MEANING OF THE CONCEPT OF ISOMORPHISM]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

MINERAL RESOURCES AND METHODS OF LOCATION AND PROSPECTING

51. Babushkin, V.A., Opredeleniye plotnosti razvedochnoy seti pri razvedke shotkverkovykh mestorozhdeniy [DETERMINATION OF THE DENSITY OF THE SURVEY NET IN PROSPECTING STOCKWORK DEPOSITS]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

52. Baratov, R.B., Osnovnyye cherty magmatizma i metallogenii Zeravshano-Gissarskoy gornoy oblasti [MAIN FEATURES OF THE IGNEOUS ACTIVITY AND METALLOGENY OF THE ZERAVSHAN-GISSAR MOUNTAIN REGION]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

53. Belevtsev, Ya.N., Rol' metamorficheskikh protsessov v rudoobrazovanii [THE ROLE OF METAMORPHIC PROCESSES IN ORE FORMATION]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

54. Blokh, A.M., Bentonitovyye gliny v Zabaykal'ye [BENTONITE CLAYS IN THE TRANSBAYKAL]: Dokl., Akademiya Nauk SSSR, t. 128, no. 5.

155. Brod, I.O., Diagnosticheskiye priznaki protsessov bitumoobrazovaniya i neftegazoobrazovaniya [DIAGNOSTIC INDICATIONS OF PROCESSES OF BITUMEN FORMATION AND OIL AND GAS FORMATION]: Novosti neft. tekhn. geologiya, no. 9.

156. Burlin, Yu.K., Perspektivy neftegazonosnosti nizhnemelovykh otlozheniy v oblasti Adygeyskogo vystupa [THE OIL AND GAS PROSPECTS OF THE LOWER CRETACEOUS DEPOSITS IN THE AREA OF THE ADYGEY PROJECTION]: Novosti neft. tekhn., geologiya, no. 9.

157. Bykhover, N.A. and A.F. Opalev, Minerol'no-syr'yevaya baza kapitalisticheskikh stran [THE MINERAL RAW MATERIAL RESERVES OF THE CAPITALIST COUNTRIES]: Razv. i okhrana nedr, no. 9.

158. Varentsov, M.I., N.T. Kurenkov and A.S. Kuznetsov., O poiskakh skopleniy nefti i gaza v Avstralii [PROSPECTING FOR OIL AND GAS ACCUMULATIONS IN AUSTRALIA]: Novosti neft. tekhn., geologiya, no. 9.

159. Gaskin, M.I., Opredeleniya minimal'no-promyshlennogo i bortovogo soderzhaniya metalla v rudakh mestorozhdeniy tsvetnykh metallov i zolota [DETERMINATIONS OF THE MINIMAL INDUSTRIAL AND ORE-BANK CONTENT OF METAL IN THE ORES OF NON-FERROUS AND GOLD DEPOSITS]: Vestn. Vost.-Sib. pravl., Chita, vyp. 1.

160. Gladysheva, G.A. and V.P. Kozlov, Metodika i rezul'taty izucheniya genezisa bitumov Tkibul'skogo kamennougol'nogo mestorozhdeniya [THE METHODS AND RESULTS OF A STUDY OF THE GENESIS OF THE BITUMENS IN THE TKIBUL' COAL DEPOSIT]: Novosti neft. tekhn., geologiya, no. 9.

161. Glazovskaya, M.A., K metodike geokhimicheskikh poiskov mednokolchedannykh mestorozhdeniy na Yuzhnom Urale [ON THE METHOD OF GEOCHEMICAL PROSPECTING FOR COPPER-PYRITE DEPOSITS IN THE SOUTHERN URALS]: Sov. geol., no. 8.

162. Gurzhiy, D.V., Soveshcmaniye po voprosu izucheniya mestorozhdeniy samorodnoy sery [THE MEETING ON THE PROBLEM OF STUDYING DEPOSITS OF NATIVE SULFUR]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

163. Donskikh, V.V., N.I. Nakovnik and Ye.V. Petrova, Novoye dyumort'yerit-

korund-andaluzitovoye mestorozhdeniye v Kazakhstane [A NEW DUMORTIERITE-CORUNDUM-ANDALUSITE DEPOSIT IN KAZAKHSTAN]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

164. Dubov, R.I., Postanovka elektrorazvedki na mestorazhdeniyakh Zabaykal'ya v usloviyakh mnogoletney i sezonnoy merzloty [THE ESTABLISHMENT OF ELECTRICAL PROSPECTING IN THE DEPOSITS OF THE TRANSBAYKAL UNDER THE CONDITIONS OF PERENNIAL AND SEASONAL FROST]: Razv. i okhrana nedr, no. 9.

165. Yerokhin, N.N., Respublikanskoye soveshchaniye geologov-razvedchikov Kazakhstana [THE ALL-REPUBLIC CONFERENCE OF EXPLORATION GEOLOGISTS OF KAZAKHSTAN]: Vestn., Akademiya Nauk KazSSR, no. 9.

166. Zerkalov, V.I., Mineralogiya i genezis rud Uskandinskoy gruppy mestorozhdeniy Salaira [THE MINERALOGY AND GENESIS OF THE ORES OF THE USKANDA GROUP OF DEPOSITS OF THE SALAIR REGION]: Vestn. Zap.-Sib. i Novosib. geol. upr., no. 3.

167. Itenberg, S.S., G.A. Shnurman and M.N. Soson, Ob opredelenii effektivnom moshchnosti kollektorov khadumskogo gorizonta Takhtinsko-Kugul'tinskoy ploshchadi [DETERMINATION OF THE EFFECTIVE THICKNESS OF THE COLLECTORS IN THE KHADUM STRATUM IN THE TAKHTA-KUGUL'TA AREA]: Novosti neft. tekhn., geologiya, no. 9.

168. Kantor, M.Z., K metodike issledovaniya pri poiskakh mestorozhdeniy bora v Tadzhikistane [METHODS OF INVESTIGATION IN SEARCHING FOR BORON DEPOSITS IN TADZHIKISTAN]: Zap. Tadzh. otd. Vses. min. o-va, vyp. 1.

169. Karpova, Ye.D., Metallogenicheskoye rayonirovaniye Tyan'-Shanya' i Pamira [A METALLOGENIC REGIONALIZATION OF THE TYAN'-SHAN' AND THE PAMIR RANGES]: Sov. geol. no. 8.

170. Kundryavtsev, N.A., Po povodu obrazovaniya nefti v karbonatnykh porodakh [ON THE FORMATION OF OIL IN CARBONATE ROCKS]: Sov. geol., no. 8.

171. Kurtserayte, Sh.D., O perspektivakh almazonosnosti yugo-zapadnoy chasti Sibirskoy platformy [THE PROSPECTS FOR DIAMOND-BEARING IN THE SOUTH-WESTERN PART OF THE SIBERIAN PLATFORM]: Sov. geol., no. 8.

172. Lebedeva, L.D., Geomorfologicheskiy analiz v pomoshch' vyboru metodiki razvedki zolotonosnykh rossypey Sever Vostoka SSSR [GEOMORPHOLOGICAL ANALYSIS AS AN AID IN SELECTING METHODS OF PROSPECTING GOLD-BEARING PLACERS IN THE NORTH-EASTERN USSR]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

173. Levin, A.I. and L.V. Levin, Novyye dannyye o stroyenii i perspektivakh neftegazonosnosti Krasnovodskogo poluostrova [NEW DATA ON THE STRUC TURE AND THE OIL AND GAS PROSPECTS OF THE KRASNOVODSK PENINSULA]: Novosti neft. tekhn., geologiya no. 9.

174. Likhachev, Yu.A., Istoriya razvitiya struktury Vostochnogo Kara-Mazara i zakonomernosti razmeshcheniya gidrotermal'nogo orudeneniya [THE HISTORY OF THE STRUCTURE OF THE EASTER KARA-MAZAR AND THE LAWS CHARACTERIZING THE DISTRIBUTION OF I HYDROTHERMAL MINERALIZATION]: Izv., Akademiya Nauk TadzhSSR, otd. yest. nauk, vyp. 1, (28).

175. Mikhaylov, I.M., Poiski novykh neftonos nykh ploshchadey v adyrnoy zone Yuzhn i Yugo-Vostochnoy Fergany [A SEARCH FOR NEW OIL-BEARING AREAS IN TH ADYRNAYA ZONE OF THE SOUTHERN AND SOUTHEASTERN FERGANA REGION]: Novosti neft. tekhn., geologiya no. 9.

176. Mogarovskiy, V.V., K voprosu talliyenosnosti nekotorykh mineralov mestoro zhdeniya Darayso (Tadzhikskaya depres siya) [ON THE THALLIUM CONTENT OF CERTAIN MINERALS OF THE DAR AYSO DEPOSIT (TADZHIK DEPRESSION Zap. Tadz. otd. Vses. min. o-va, vyp.

177. Naumov, V.P., O poloschatykh tekstura rud kolchedanno-polimetalicheskikh me torozhdeniy Irtyshskoy zony smyati ya v Rudnom Altaye [ON THE BANDED TE TURES OF THE ORES IN THE PYRITIC POLYMETALLIC DEPOSITS OF THE IRTYSH ZONE OF FOLDING IN THE RUDNYY ALTAY]: Zap. Vses. min. o-va, ch. 88, vyp. 5.

178. Per'kov, N.A., O metodike opredeleniy effektivnoy moshchnosti glinistykh kollektorov [ON THE METHOD OF DETERMINING THE EFFECTIVE THICKNESS OF CLAY COLLECTORS]: Novo neft. tekhn., geologiya, no. 9.

179. Rusakov, M.P., O neobkhodimosti i o metodike poiskovo-razvedochnykh rab

na korund v Tsentral'nom Kazakhstane [ON THE NECESSITY AND THE METHODS OF PROSPECTING FOR CORUNDUM IN CENTRAL KAZAKHSTAN]: Vestn., Akademiya Nauk KazSSR, no. 9.

180. Seliverstova, M.I., Inskoye, zhelezorudnoye mestorozhdeniye [THE INSKOYE IRON-ORE DEPOSIT]: Vestn. Zap.-Sib. i Novosib. geol. upr., no. 3.

181. Selin, Yu.I., O vozraste i genezise margantsevykh rud Bol'shetokmakskogo rudnogo rayona [THE AGE AND GENESIS OF THE MANGANESE ORES OF THE BOL'SHETOKMAK ORE DISTRICT]: Dopovidi, Akademiya Nauk URSR, no. 9.

182. Sinyakov, V.I. and N.M. Sinyakova, Brusitovyye mramory Lespromkhoznogo zhelezorudnogo mestorozhdeniya [THE BRUCITE MARBLES OF THE LESPROMKHOZ IRON-ORE DEPOSIT]: Vestn. Zap.-Sib. i Novosib. geol. upr., no. 3.

183. Sirotina, T.V., Nekotoryye dannyye o kollektorskikh svoystvakh peschanikov neftyanykh mestorozhdeniy Skibovoy zony Karpat [SOME DATA ON THE RESERVOIR PROPERTIES OF THE SANDSTONES IN THE OIL DEPOSITS OF THE SKIBOVAYA ZONE IN THE CARPATHIANS]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

184. Smirnov, S.M. and A.I. Perslygina, O nekotorykh osnovnykh chertakh stroyeniya i rudo nosnosti massivov osnovnykh i srednikh porod v khrebte Monostoy (Buryatskaya ASSR) [SOME BASIC FEATURES OF THE STRUCTURE AND ORE CONTENT OF THE BASIC AND INTERMEDIATE ROCK MASSIFS IN THE MONOSTAYA RANGE (THE BURYAT ASSR)]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

185. Tikhonov, A.N. and V.I. Dmitriyev, O vozmozhnosti primeneniya induktsionnogo metoda aeroelektrorazvedki dlya geologicheskogo kartirovaniya [ON THE POSSIBILITY OF USING THE INDUCTION METHOD OF AERIAL ELECTRIC PROSPECTING FOR GEOLOGIC MAPPING]: Izv., Akademiya Nauk SSSR, ser. geofiz., no. 9.

186. Ushakov, S.A., Fizicheskiye svoystva gornykh porod Vostochnoy Antarktidy i vozmozhnost' primeneniya razlichnykh metodov geofizicheskoy razvedki [THE PHYSICAL PROPERTIES OF THE ROCKS OF EASTERN ANTARCTICA AND THE POSSIBILITY OF USING VARIOUS GEOPHYSICAL EXPLORATION METHODS]: Inform. byul. Sov. Antarkt. eksp, no. 6.

187. Fedynskiy, V.V., Perspektivy razvitiya geofizicheskikh metodov poiskov i razvedki mestorozhdeniy poleznykh iskopayemykh v SSSR na 1959-1965 gg. [THE PROSPECTS FOR THE DEVELOPMENT OF GEOPHYSICAL METHODS OF PROSPECTING AND LOCATING DEPOSITS OF ECONOMIC MINERALS IN THE USSR FROM 1959 TO 1965]: Sov. geol., no. 8.

188. Shainskiy, A.M. and B.O. Gaman, Primeneniye elektrorazvedki dlya poiskov vod v mergelyakh melovogo vozrasta vo L'vovskoy mul'de [THE USE OF ELECTRICAL PROSPECTING IN THE SEARCH FOR WATER IN THE CRETACEOUS MARLS OF THE L'VOV BASIN]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

189. Shipulin, F.K., Gidrotermal'noye mestorozhdeniye samorodnoy sery v Mongol'skoy Narodnoy Respublike [A HYDROTHERMAL DEPOSIT OF NATIVE COPPER IN THE MONGOLIAN PEOPLE'S REPUBLIC]: Sov. Geol., no. 8.

190. Shcherba, G.N., Kurchumskoye mestorozhdeniye tal'ka i breynerita [THE KURCHUM TALC AND BREUNNERITE DEPOSIT]: Vestn., Akademiya Nauk KazSSR, no. 9.

191. Shcherban, I.P., Rudoproyavleniya grafita v granitakh rapakivi vostochnoy chasti Korostenskogo plutona [GRAPHITE ORE OCCURRENCES IN THE RAPAKIWI GRANITES OF THE EASTERN PART OF THE KOROSTENSKIY PLUTON]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

HYDROGEOLOGY AND ENGINEERING GEOLOGY

192. Al'bov, Ye.V., K voprosu o neftyanykh vodakh neogena Prichernomorskoy vpadiny [THE PROBLEM OF THE OIL-BEARING WATERS IN THE NEOGENE ROCKS OF THE BLACK SEA BASIN]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

193. Akhundov, A.R. and Ya.M. Bashirov, K voprosu gidrokhimicheskoy inversii plastovykh vod svity PK yugo-zapadnogo kryla mestorozhdeniya Neftyanyye Kamni [THE PROBLEM OF THE HYDROCHEMICAL INVERSION OF THE STRATAL WATERS IN THE CARBONIFEROUS-PERMIAN SEQUENCE IN THE SOUTHWESTERN FLANK OF THE NEFTYANYYE KAMNI DEPOSIT]: Azerb. neft, kh-vo, no. 8.

194. Bagirzade, F.M., Khimicheskaya kharakteristika plastovykh vod kalinskoy svity

Apsheronskogo arkhipelaga [A CHEMICAL CHARACTERIZATION OF THE STRATAL WATERS OF THE KALINSKAYA SUITE OF THE APSHERON ARCHIPELAGO]: Azerb. neft. kh-vo, no. 8.

195. Dobrovol'skiy, V.P., Nekotoryye osobennosti interpretatsii krivykh VEZ poluchennykh pri issledovanii tolshchi mnogoletnemerzlykh gornykh porod [SOME ASPECTS OF THE INTERPRETATION OF ELECTRICAL LOGGING CURVES OBTAINED IN STUDYING PERENNIALLY FROZEN ROCKS]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

196. Zubrova, Ye.A., Osobennosti gidrogeologii yugo-vostochnoy chasti Gornogo Kryma [SOME FEATURES OF HYDROGEOLOGY IN THE SOUTHEASTERN PART OF THE CRIMEAN MOUNTAINS]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

197. Kashtanov, S.G., Izmeneniye kachestvennogo sostava vody ozera Sredniy Kaban pod vliyaniyem gidrostaticheskogo davleniya Kuybyshevskogo vodokhranilishcha [THE CHANGE IN THE QUALITATIVE COMPOSITION OF THE WATERS OF LAKE SREDNIY KABAN UNDER THE HYDROSTATIC PRESSURE OF THE KUYBYSHEV RESERVOIR]: Nauchn. dokl. vyssh. shkoly., geol.-geogr. nauki, no. 2.

198. Knertser, V.G., Zavisimost' velichiny debita ot snizheniya i radiusa skvazhiny [THE RELATIONSHIP OF THE DISCHARGE MAGNITUDE TO THE DEPTH AND RADIUS OF THE WELL]: Geol. zh., Akademiya Nauk USSR, t. 19, vyp. 4.

199. Kovalevskiy, V.S., Klassifikatsionnaya skhema yestestvennogo rezhima gruntovykh vod [A CLASSIFICATION SYSTEM FOR THE NATURAL REGIMES OF GROUND WATERS]: Razv. i okhrana nedr, no. 9.

200. Lepezin, P.A., O vozmozhnosti uvelicheniya debita, radioaktivnosti i temperatury belokurikhinskikh term [ON THE POSSIBILITY OF INCREASING THE DISCHARGE, THE RADIOACTIVITY AND THE TEMPERATURE OF THE BELOKURIKHA HOT SPRINGS]: Vest. Zap.-Sib. i Novosib. geol. upr., no. 3.

201. Maksimovich, G.A., Osnovnyye tipy i modul' podzemnogo stoka karstovykh oblastey [THE UNDERGROUND FLOW MODULE AND THE BASIC TYPES OF KARST REGIONS]: Dokl., Akademiya Nauk SSSR, t. 128, no. 5.

202. Panteleyev, Ye.R., Kharakternyye inzhinerno-geologicheskiye osobennosti porod slagayushchikh pody Khersonskoy oblasti [THE TYPICAL ENGINEERING GEOLOGIC PROPERTIES OF THE ROCKS COMPOSING THE BASEMENT OF THE KHERSON REGION]: Nauchn. dokl. vyssh. shkoly, geol.-geogr. nauki, no. 2.

203. Rogov, G.M., Nekotoryye voprosy gidrogeokhimii podzemnykh vod Belovskogo rayona Kuzbassa [SOME PROBLEMS OF THE HYDROGEOCHEMISTRY OF THE GROUND WATERS IN THE BELOV AREA OF THE KUZNETS BASIN]: Vestn. Zap.-Sib. i Novosib. geol. upr., no. 3.

204. Smirnov, A.A., O metodike izucheniya potentsialov fil'tratsii v ruslakh rek [ON THE METHODS OF STUDYING THE FILTRATION POTENTIALS IN RIVER CHANNELS]: Nauchn. dokl. vyssh. s shkoly, geol.-geogr. nauki, no. 2.

205. Fokeyev, V.M., Opredeleniye davleniya nasyshcheniya uglekisloty v vode [DETERMINATION OF THE SATURATION PRESSURE OF CARBONIC ACID IN WATER]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 6.

B. Papers in "Materialy," "Trudy," "Uchenyye Zapiski," and "Sborniki"

1. Voprosy biostratigrafii kontinental'nykh tolshch. M., 1959. 244 s. [Problems of the Biostratigraphy of Continental Sequences], Moscow, 1959. 244 pp. Partial contents: Gorskiy, I.I., On the biostratigraphy of continental deposits. Gur'yanova, Ye.F., Theoretical principles of preparing submarine topographic maps. Martinson, G.G., The importance of mesozoic fresh-water molluscs in the stratigraphic subdivision of the continental deposits of Asia. Kolesnikov, Ch.M., The significance of the fresh-water molluscs for the stratigraphy of the Mesozoic continental deposits of the Transbaykal. Stepanov, V.V., The molluscs of the fluvial and lagoonal-marine deposits of the Odessa lagoons. Zaspelova, V.S., The significance of phyllopod crustaceans for the stratigraphy of the Carboniferous continental deposits of Kazakhstan. Miroshnichenko, B.Ye., The significance of phyllopod crustaceans for the biostratigraphy of the Carboniferous deposits of the Karaganda Basin. Sheremeta, V.G., The significance of ostracodes in the stratigraphic subdivision of the deposits in the Pannon fresh-water basin in the Transcarpathia. Kaz'mina, T.A., Mesozoic and Cenozoic

fresh-water ostracodes of the Western Siberian lowland. Lyutkevich, Ye.M. and O.V. Lobanova, Concerning the Early Permian age of the Alykayev fauna of the Kuznets Basin. Repman, A.Ye., On the changes in the morphology of the shells of certain Jurassic pelecypods in relation to the ecologic conditions. Khozatskiy, L.I., The paleontological significance of fossil skull remains. Bazhanov, V.S., The importance of Tertiary mammals and reptiles in the stratigraphic subdivision of the sedimentary strata of Kazakhstan. Bystrov, A.P., The microstructure of the armor plates of arthrodires. Samoylova, R.B., New data on the study of trochiliscids. Khlonova, A.F., The significance of individual forms of spores and pollen for the correlation of continental deposits. Senkevich, M.A., The paleobotanical basis for the stratigraphy of the continental facies in the Devonian deposits of Kazakhstan. Chirkova-Zalesskaya, Ye. F., On the age of the Devonian terrigenous red beds of Siberia. Kedo, G.I., The significance of spore-pollen analysis in the stratigraphy of the continental deposits in the lower strata of the Carboniferous system in Belorussia. Sikstel', T.A., The morphological peculiarities of the Late Permian and Early Triassic plants of the Southern Fergana region, as determined by ecological causes. Kuzichkina, Yu.M., Ye.A. Repman and T.A. Sikstel', An attempt at a stratigraphic subdividion of the Lower Mesozoic continental deposits of Central Asia. Shtempel', B.M., The use of the paleophytological method in the stratigraphic subdivision of the Mesozoic continental deposits of the Southern Primor'ye region. Popova, A.D., The paleobotanical basis for the stratigraphy of the Upper Cretaceous deposits of Northeastern Asia (based on materials of A.N. Krishtofovich and papers of the Kolyma geologists). Zaklinskaya, Ye.D., The paleofloristic basis for the stratigraphic subdivision of the Cenozoic deposits of Kazakhstan and the adjacent parts of the Western Siberian Lowland. Kornilova, V.S., The significance of floristic assemblages for the stratigraphic subdivision of the Tertiary rocks of the Turgay River basin and the Pavlodvar area of the Irtysh region. Voroshilova, A.G., The stratigraphy of the lagoonal-continental (saliniferous) Miocene deposits of the Nakhichevan ASSR and their correlation with the marine deposits in the southern part of the USSR. Popov, G.I., The correlation of the marine and alluvial deposits of the Evksa-Caspian basin according to paleontological data. Zhuze, A.P., The paleogeography of the Far Eastern Seas (based on analysis of the diatoms in the bottom deposits).

2. Voprosy geografii, sb. 46 M., 1959, 266 s. [Problems of Geography], Sb. 46, Moscow, 1959, 266 pp. From the contents: Voskresenskiy, S.S., Geomorphological regionalization of the southern part of Siberia. Zagorskaya, N.G., The nature of the ancient glaciation of peneplanes, based on materials on the present glaciation of the Severnaya Zemlya archipelago. Mitt, K.L., Concerning the nature of the dells in the Daldyn region. Nevesskiy, Ye.N., The study of littoral deposits as a method of paleogeographic reconstruction of marine shorelines. Zorin, L.V., The channel-forming activity of some rivers of Eastern Siberia. Popov, A.I., The history of the relief in the Berelekh River basin. Myakokin, V.S., Concerning the role of vertical movements in the development of the shores of Lake Baykal. Shcherbakova, Ye.M., The role of disjunctive dislocations in producing the mountain relief of Southern Siberia. Korzhuyev, S.S., On the geomorphology of the Middle Lena valley and the adjoining parts of the Lena plateau. Voskresenskiy, S.S., Tectonic relief forms. Spiridonov, A.I., Concerning the concept of "type relief". Korzhuyev, S.S., and D.A. Timofeyev, On geomorphological terminology. Lebedeva, N.A., On the importance of discovering and mapping relief complexes of the same age in analyzing recent movements. Rukhina, Ye. V., Pseudomoraines. Kaplina, T.N., Some special features of downslope movements in areas of perennially frozen rocks. Kaplin, P.A., The problem of the origin of the fjords and fjord shorelines of the USSR. Gornung, M.B., New data on the geomorphology of the Central Sahara. Grave, N.A., On the "permafrost" in North America and the forms of mesorelief and microrelief associated with the perennially frozen rocks in Alaska. Byudle', Yu., Stages in the development of relief and changes in the Pliocene and Pleistocene climate in the Khoggar Mountains of the Central Sahara. Makhachek, F., The Surface of the earth: an Attempt at a Regional Morphological Description of the Earth's Surface; Berlin, 1955; Vol. 1, 531 pp.; Vol. 2, 594 pp. (review).

3. Voprosy geografii Kazakhstana, vyp. 5. Alma-Ata, 1959, 221 s. [Problems of the Geography of Kazakhstan], Vyp. 5, Alma-Ata, 1959, 221 pp. Partial contents: Popov, A.V., The formation of the surface of the lower part of the Iliyskiy basin. Gerasimov, V.A., The problem of the ancient glaciation in the basin of the Bayankol River. Chigarkin, A.V., The topographies in the territory of the Aral-Dzhezkazgan region. Popova, G.Z., Some special features of the relief of Mt. Byn

in Central Kazakhstan.

4. Materialy VSEGEI, Nov. ser. Vyp. 2, chetvertichn. geol. i geomorf. L., 1959, 198 s. [Materials of VSEGEI, New Series, No. 2, Quaternary Geology and Geomorphology]: Leningrad, 1959, 198 pp. Contents: S.A. Yakovlev, Obituary. S.G. Boch, Obituary. Yakovlev, S.A., The conference on the development of a unified stratigraphic scheme for Siberia. Zubakov, V.A. and I.I. Krasnov, Principles of stratigraphic subdivision of the Quaternary system and the project of a single stratigraphic scale for the Quaternary. Shul'ts, S.S. and S.V. Epshteyn, On the tasks and the position of geomorphological surveying and the surveying of Quaternary deposits in the complex of operations concerned with state geological mapping. Ganeshin, G.S., The stratigraphy of the Late Tertiary and Quaternary deposits of the Sikhote-Alin and Primor'ye regions. Chemekov, Yu. F., The Quaternary system of the Khabarov district and the Amur region. Verbitskaya, N.P., The stratigraphy and lithology of the alluvial deposits in the diamond-bearing areas on the western slopes of the Middle Urals. Zubakov, V.A., The geomorphological structure of the middle and lower reaches of the Yenisey River valley. Ganeshin, G.S., The Quaternary glaciation in the Sikhote-Alin Range. Seliverstov, Yu.P., The Quaternary glaciation of the Southern Altay. Nekhoroshev, V.P., The Quaternary tectonics of the Altay. Vlasov, G.M., High-altitude weathering surfaces in Kamchatka and the Kurile Islands. Solov'yev, V.V., The Holocene ingression in the Southern Primor'ye area.

5. Materialy po geologii rudnykh mestorozhdeniy, petrografii, mineralogii i geokhimii. M., 1959, 424 s. [Materials on the Geology of Ore Deposits, on Mineralogy and Geochemistry]: Moscow, 1959, 424 pp. Contents: Malinovskiy, Ye.P., Some problems of the genesis of the gently dipping quartz-wolframite veins of the Bukuka deposit. Pavlov, D.I., Some features of the mineralization in the Yakovlev iron-ore deposit (Eastern Transbaykal). Dubrovskiy, V.N. and V.P. Polokhov, Some peculiarities of the structure and zonality of the ore mineralization in the Lifudza ore field. Aleksandrov, A.I., The occurrence of primary zonality in the veins of the Stalinsk tin-polymetallic deposit. Tsigikalova, T.N., Types of ores and stages of mineralization in the Akchagyl polymetallic deposit (Central Kazakhstan). Kravchenko, G.G., On the chronological succession of igneous rocks in the northern foothills of the Alayskiy Range. Nekrasov, Ye.M., The scale of hydrothermal mineralization as a function of the orientation of the veins relative to the bedding of the rocks. Vinokurov, P.K., The Denislav bauxite deposit. Gipp, S.K., On the genesis of the Kayrak bauxite deposit. Mukanov, K.M., Some features of the formation of the primary dispersion halos in ore deposits. Bugel'skiy, Yu.Yu., On the possibility of instituting geochemical prospecting operations for beryllium. Vinogradov, V.I., Some problems of the hydrogeochemistry of molybdenum. Kalita, Ye.D., On the problem of the dispersion halos of lithium, rubidium and beryllium. Bugel'skiy, Yu. Yu., The migration of ore components in the ground waters of the polymetallic deposits of the Eastern Transbaykal. Serebrennikov, V.S., Seasonal changes in the uranium content of ground waters. Bogdanova, V.I., The chromatographic distinction between titanium and niobium and tantalum and their separation. Churikov, V.C., Some features of the chemical composition of wolframites. Lebedev, L.M., The mineralogy of the Iokun'sh lead-zinc deposit. Smol'yaninova, N.N. and V.A., Moleva, The discovery of bavenite in the skarns of the Batystau deposit (Central Kazakhstan). Mozgova, N.N., Hypogene alterations of the hedenbergite in the skarn-polymetallic deposit of the Upper Mine (Tetyukhe). Yermilova, L.P. and V.M. Senderova, Strontianite from the Western Karaoba deposit in Central Kazakhstan. Tsigikalova, T.N., Aikinite from the Akchagyl deposit. Pertsev, N.N., and I.B. Nikitina, Fluoborite from Southern Yakutia. Lukanina, M.I., The mineral composition of the ores in the Sokolov and Odinsk deposits of the Kamen district (Middle Urals). Zheru, M.I., A method of field identification of calcite and dolomite in the Slyudyanka Archean marbles. Strelyanov, N.P., A method of rapid approzimate quantitative determination of the minerals in heavy concentrates. Pertsev, N.N., The wollastonite-bearing and silicate-carbonate rocks of the Dzheltula series of the Archean system in the Aldan shield. Dmitriyev, Yu. I., The metasomatic carbonate rocks of Mt. Chavida. Yefremova, S.V., The xenoliths in the granites of the Eastern Kounrad intrusives (Central Kazakhstan). Khryanin, L.P., A diabase-monzonite from the Uchama River area. Levin, V.N. and V.B. Meshcheryakova, Volcanic chimneys and their spatial position within the Kurama Range. Pavlov, V.A., On the relationship between the joint tectonics of certain intrusives of Central Kazakhstan and the tectonics of the surrounding rocks. Omel'yanenko, B.I. and N.A. Sirotinin, Accessory minerals in the alkaline rocks in the area of the upper reaches of the Khodzha-Achkan River.

Materialy iv Vsesoyuznoy konferentsii po selevym potokam. Alma-Ata, 1959. 231 s. [Materials of the Fourth All-Union Conference on Eroding Flood Waters]: Alma-Ata. 1959 231 pp. Partial contents: Yermakov, A.V., An experimental geomorphological investigation of flood basins (on the example of the river basins in the Main Caucasus in the area of the Georgian military highway). Kolotilin, N.F., The geological conditions of formation of some locally occurring floods from the example of the floodstream of the Lesser Almatinka River valley on August 7, 1956).

Mineralogicheskiy sbornik L'vovskogo geologicheskogo obshchestva pri universitete, no. 13. L'vov, 1959. 475 s. [Collection of Articles on Mineralogy of the Geological Society of the University of L'vov]: No. 13, L'vov, 1959, 475 pp. Contents: Lazarenko, Ye K., and Ye.P. Slivko, Recent developments in the mineralogy of the western areas in the Ukrainian SSR. Belov, N.V.Kh., Notes on structural mineralogy. Bokiy, G.B. and T.S. Khodashova, The crystallochemistry of indium. Gurzhiy, D.V. and L.G. Tkachuk, On the step-like (imbricated) form of garnets. Shafranovskiy, I.I., The crystallomorphic description of microcrystalline minerals. Povarennykh, A.S., Calculation of the hardness of minerals according to the Mohs Scale on the basis of crystallochemical data. Zolotukhin, V.V., and V.P. Kostyuk, On the graphic depiction of the relationship between the angle of the optical axes and the birefringence of one of the principal sections in plagioclase. Grum-Grzhimaylo, S.V., The coloration of the nickel minerals in the weathering crust. Sobolev, V.S., The phase relationships in the nepheline—calcinite—anorthite—silica system. Slivko, M.M., On manganiferous tourmalines. Laz'ko, Ye.M., On the occurrences of recrystallization in the formation of quartz crystal veins. Nalivkina, E.B., The metasomatic zonality and the genesis of the sapphirine-containing rocks of the Bug River region. Ivanov, M.V., The role of sulfate-reducing bacteria in the formation of the hydrogen sulfide in the ground waters of the Upper Tortonian deposits. Shashkina, V.P., The mineralogy of the weathering crust of the basalts in Western Volhynia. Boldyreva, T.A. andYe.P. Slivko, Mineral inclusions in the coals of the L'vov-Volhynian Basin. Sidorenko, Ye.F., The mineralogy of the clays along the Odessa shore of the Black Sea. Lesnyak, V.F. and Ya.L. Giller, Wehrlite and native bismuth from Transcarpathia. Yeliseyev, E.N., Determination of the dimensions of the unit cells of clay minerals from X-ray powder patterns (debayegrams). Tsigikalova, T.N., Some intergrowths of bismuth minerals inthe Akchagyl polymetallic deposit. Bur'yanova, Ye.Z., On the succession in the formation of the minerals in the nepheline-syenite pegmatites of the Vishnev Mountains in the Urals. Butakova, Y.L., The role of metasomatism in the formation of alkaline rocks. Vartanova, N.S. and R.Ya. Epshteyn, Clinozoisite from the metasomatic rocks near Kamenka in the Dnepropetrovsk region. Shevchenko, Ye.V., The amphiboles of the Krivoy Rog metamorphic series. Gnativ, G.M., The mineralogy of the hybridized quartz diorites in the vicinity of Golychevka in Western Volhynia. Ushakova, Ye.N., Some aqueous silicates from Zaval'ye in the Middle Urals. Bobrovnik, D.P., Siderite formations in the coal measures of the L'vov-Volhynian coal basin. Gabinet, M.P., The dolomites and siderites of the melinite series in the Soviet Carpathians. Proshchenko, Ye.G., A natural tetravalent magnesium sulfate. Lazarenko, Ye.K. and B.I. Srebrodol'skiy, The morphology of the native sulfur in the Dnestr River region. Koltun, L.I., Syngenetic solid inclusions in rock crystal. Sobolev, N.V., A garnet from the Kolmozero pegmatites. Lavrenko, Ye.I., and Ye. M. Laz'ko, Three chlorites from quartz-crystal veins. Mel'nik, Yu.M., Corrensite (vermiculite-chlorite) from the gabbro diabases of Volhynia. Zvyagin, B.B., and V.A. Frank-Kamenetskiy, on the subject of beidellite. Rupin, M.B., Barite from the sedimentary rocks of the Eastern Carpathians. Srebrodol'skiy, B.I., Jarosite from the vicinity of Sinyak in Transcarpathia. Litvinenko, A.U. and N.Z. Khmarskiy, A β-kerchenite from the Quaternary alluvial deposits of the Dnepr River in the vicinity of Dneprodzerzhinsk. Lazarenko, E., New mineralogical discoveries in the metasomatic rocks of the Vygorlat-Guta volcanic ridge (Transcarpathia). Professor D.P. Grigor'yev: Anniversary. The fiftieth anniversary of the birth of Professor G.B. Bokiy, Corresponding Member of the Academy of Sciences of the USSR. The seventy-fifth anniversary of the birth of A.N. Savaritskiy. Petrov, V.P., Mineralogical crystallography. Maksimenko, F.F., The literature on the mineralogy of the Ukraine in 1958. In memoriam: St.I. Tugutt. Slivko, M.M., The Fedorov conference on crystallography. Rus'ko, Yu.A., The spring meeting of the Clay Minerals Group of the Mineralogical Society of Great Britain. Rus'ko, Yu.A., The meeting of the X-ray Analysis Group of the Institute of Physics of Great Britain.

8. Nauchnyye trudy Moskovskogo gornogo instituta, sb. no. 28, M., 1959. 146 s.

[Scientific Papers of the Moscow Institute of Mining]: Sb. No. 28, Moscow, 1959, 146 pp. Contents: A.A. Gapeyev, Obituary. Troyanskiy, S.V., The trends in scientific research work in geology in the Moscow Mining Academy and the Mining Institute. Dorokhin, I.V., On the types and distribution of coal deposits with thick seams in the USSR. Platonov, N.Kh., Some features of the formation and composition of the combustible shales of the Russian platform. Panyukov, P.N., The rock massif—the basic object of studies in engineering geology. Peresun'ko, D.I., The hydrogeology of the sulfur deposits of Central Asia.

9. Soveshchaniye po geologicheskomu stroyeniyu i mineral'nym resursam Sibirskoy platformy, vyp. 1. Alma-Ata, 1959, 72 s. [The Conference on the Geologic Structure and the Mineral Resources of the Siberian Platform]: Vyp. 1, Alma-Ata, 1959, 72 pp. Contents: Odintsov, M.M., The chief epochs of formation of economic minerals in the development of the Siberian platform. Dzevanovskiy, Yu.K., The Precambrian complexes of the Aldan shield and the Stanovoy Range. Lavrov, M.M., The Siberian platform and the problem of the Sinian system. Trufanova, A.P., The stratigraphy of the Ordovician system in the Irkutsk amphitheater. Charushin, G.V., The regional systems of tectonic faults in the Siberian platform. Kurtserayte, Sh.D., The diamond content of the southwestern part of the Siberian platform. Sayntsev, F.M., Some special features of the magnetite mineralization in the western part of the Siberian platform. Bogatskiy, V.V., The titanium metallogeny in the igneous rock complexes of the western part of the Siberian platform. Kitaynik, A.F. and V.S. Tkalich, The titanium in the Mesozoic and Cenozoic deposits and traprocks of the margin of the Siberian platform. Dolgov, F.G., The occurrence of placers of titanium minerals in the Irkutsk region. Dolgov, F.G. and Z.N. Lobeyeva, The titanium content of the Jurassic sandstones in the southern part of the Siberian platform. Bessolitsyn, Ye.P., An experiment in preparing prognostic maps for bauxites in the Irkutsk coal basin. Tkachuk, V.G. and Ye.V. Pinneker, The hydrogeological regionalization of the Siberian platform. Ivanov, A. A., The Lower Cambrian halogenic formations of the Siberian platform. Strugov, A.S., The stratigraphy of the Mesozoic coal measures in the southwestern part of the Vilyuy syneclise. Lyuber, A.A., New data on the origin of certain coals of the Tungusska Basin. Lushikhin, G.M., The petrography of the coals in the basin of the middle reaches of the Lower Tunguska River. Nikol'skiy, V.M., The conditions of formation of the coal measures in the southwestern part of the Tungusska Basin. Bochkovskiy, F.A. and G.M. Lushchikhin, A prognostic evaluation of the prospects for discovering coking coals in the Tungusska coal basin. Ivanov, N.V., The conditions of formation of the Mesozoic coal-bearing deposits of the Lower Aldan area of the Leninsk Basin.

10. Tektonika SSSR, t. 4., M., 1959, 462 s. [The Tectonics of the USSR]: T. 4, Moscow, 1959, 462 pp. Contents: Offman, P.Ye., The tectonics and volcanic pipes of the central part of the Siberian platform. Chumakov, N.M., The stratigraphy and tectonics of the southwestern part of the Vilyuy River valley.

11. Trudy VNIGNI, vyp. 13. M., 1959, 319 s. [Publications of the All-Union Scientific Research Institute of Oil Geology]: Vyp. 13, Moscow, 1959, 319 pp. Contents: Veselovskaya, M.M., D.N. Utekhin and S.M. Sukhanova, The Proterozoic formations of the Russian platform, on the basis of data from deep drilling. Veselovskaya, M.M., Ancient weathering crusts on the Russian platform, as determined by deep drilling. Larionova, Ye.N. and V.N. Tikhomirova, The Bavla deposits of the Perm region and the Udmurt ASSR. Filippova, M.F. and S.M. Aronova, The lithology and conditions of formation of the Devonian deposits in the Ul'yanov area of the Volga region. Filippova, M. F., Z.A. Chernyshevskaya and G.V. Dement'yeva, The stratigraphy and paleogeography of the carbonate deposits of the Upper Devonian in the Tatar ASSR and the adjoining territories. Shabayeva, Ye.A. and L.I. Gorbunova, The petrography and mineralogy of the Devonian and Carboniferous clays of the Saratov area of the Volga region. Aprodova, A.A., The carbonaceous deposits of the Perm area on the Kama River Safonova, T.P., and K.S. Shershnev, On the stratigraphy and paleogeography of the Lower Carboniferous deposits of the Perm area on the Kama River. Makarova, T.V. and N.A. Gornshteyn, The Permian deposits in the Buzuluk test well (on the southeastern slopes of the Russian platform). Rozanov, L.N., Main features of the tectonic structure of the platform part of Bashkiria. Abrikosov, I.Kh. and P.A. Sofronitskiy, The geologic structure and oil content of the Upper and Middle Kama River areas. Nechitaylo, S.K., The geologic structure of the northern part of the Alatyr-Gor'kov zone of uplift. Getsen, V.B., The bituminological properties of

the rocks in the Perm area of the Kama River territory, as determined by luminescence-bituminological studies. P'yankov, N. A., The laws characterizing the changes in the gas saturation and other properties of the stratal oils in the Kama region. Baldina, A. L. and Sverdlov, Ya. G., The calcium-chloride waters of the Perm area in the Kama region. Zaydel'son, M. I., The hydrogeology of the Lower Carboniferous terrigenous strata in the region of the Middle Volga River.

2. Trudy geograficheskogo obshchestva Gruzinskoy SSR, t. 4, Tbilisi, 1959, 226 s [Papers of the Geographical Society of the Georgian SSR]: T. 4, Tbilisi, 1959, 226 pp. Partial contents: Dzhavakhishvili, A. N., The principles of geomorphological characterization of mountainous localities and the methods of geomorphological mapping. Nemainishvili, S. N., Some geomorphological peculiarities of the Dumal and Mechkhetur River basins. Kipiani, Sh. Ya., Geomorphologic features of the karst areas of the Upper Imeret highland. Tintilozov, Z. K., Earth slides and rock falls in the Kviril River basin. Apkhazava, I. S., The present glaciers and the traces of ancient glaciation in the Aragvi River basin. Lezhava, V. M., Floods in the basin of the Lapiani-Khevi River (a left tributary of the Iori River). Tsereteli, D. V., Some problems of the geomorphology and geology of the Lenin peak (in the Pamirs). Vladimirov, L. A., The karst waters of Georgia and their effect on the river drainage.

3. Trudy instituta geologii i poleznykh iskopayemykh. Akademiya Nauk LatvSSR, t. 3. Riga, 1959. 256 s. [Papers of the Institute of Geology and Economic Minerals of the Academy of Sciences of the Latvian SSSR]: T. 3, Riga, 1959, 256 pp. Partial contents: Liyepin'sh, P. P., The Devonian deposits of the Daugav River valley. Klyavinya, A. Ya., Economic minerals of theDaugav River valley within the Latvian SSR. Grinberg, E. F. and V. G. Ul'st, Main stages in the development of the area of theDaugav River mouth in late glacial and post-glacial times. Skuodis, V. P., An ancient buried valley in the area of the Lautse River's discharge into the Daugav River. Varfolomeyeva, O. M., Karst phenomena in the valleys of the Daugav and Lautse Rivers.

4. Trudy instituta geologii rudnykh mestorozhdeniy, petrofrafii, mineralogii i geokhimii. Akademiya Nauk SSSR, vyp. 29. M., 1959. 183 s [Papers of the Institute of the Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry of the Academy of Sciences of the USSR]: Vyp. 29, Moscow, 1959, 183 pp. Contents: Lebedev, A. P., Differentiation in the traprock intrusives of the Vilyuy Mountains. Gon'shakova, V. I., The problem of the relationship of the magnetite mineralization to the tectonic structures and igneous activity of the southeastern part of the Siberian platform. Khryanina, L. P., The alkaline differentiates of the traprock magma in the Bakhta River basin (Siberian platform). Ginzburg, I. V., Contact reactions between rare-metal-lithium pegmatites and basic rocks.

15. Trudy Laboratorii geologii uglya, Akademiya Nauk SSSR, vyp. 9. M.–L. 1959 343 s. [Papers of the Laboratory of Coal Geology of the Academy of Sciences of the USSR]: Vyp. 9, Moscow-Leningrad, 1959, 343 pp. Contents: Zaspelova, V. S., L. P. Monakhova and L. S. Bushmina, The biostratigraphy of the coal measures in the Karaganda basin. Monakhova, L. P., Viséan brachiopods from the lower part of the coal measures of Central Kazakhstan. Vostokova, V. A., Lower Carboniferous gastropods from the coal measures of the Karaganda Basin and the Zav'yalov deposit. Aleksandri-Sadova, T. A., The age of the lower formations in Karaganda on the basis of the lamellibranchiate pelecypod marine fauna. Bushmina, L. S., Carboniferous ostracodes from the coal measures of Central Kazakhstan. Sergeyev, V. V., Fresh-water lamellibranchiate molluscs of the Samara coal deposit. Zaspelova, V. S., Dimyarian phyllopod crustaceans from the top of the Carboniferous coal measures in Central Kazakhstan.

16. Trudy Novocherkasskogo politekhicheskogo instituta, t. 75. Novocherkassk, 1959. 93 s. [Papers of the Novocherkassk Polytechnical Institute]: T. 75, Novocherkassk, 1959, 93 pp. Contents: Posokhov, Ye. V., On the formation of the chemical composition of the ground waters of Central Kazakhstan. Goncharov, P. D., The ground waters of the Mesozoic and Cenozoic deposits in the Don-Donets Basin. Gordeyev, P. V., On the formation of lenses of fresh and brackish ground waters in the Black Lands. Gordeyev, P. V., Results of an analysis of the data recorded at the lysimetric station at Chernozemel'sk (Naryn-Khuduk), during the observation period from October 1, 1955 to December 31, 1956.

17. Trudy Sibirskogo nauchno-issledovatel'skogo instituta geologii, geofiziki i mineral'nogo syr'ya M-va geol. i okhrany nedr SSSR, vyp. 5. M., 1959, 128 s. [Papers of the Siberian Scientific Research Institute of Geology, Geophysics and Mineral Raw

Materials of the Ministry of Geology and Conservation of Mineral Resources of the USSR]: Vyp. 5, Moscow, 1959, 128 pp. Contents: Vinkman, M.K., The stratigraphy of the Properozoic, Sinian and Cambrian deposits of the Gornyy Altay. Sennikov, V.M., et al., The Cambro-Ordovician and Ordovician deposits of the Gornyy Altay. Gintsinger, A.B., Materials on the stratigraphy of the Silurian and Devonian deposits of the Gornyy Altay. Vasil'kovskiy, N.P., On the theory of the earth's crust.

18. Trudy Ukrainskogo nauchno-issledovatel'skogo geologorazvedochnogo instituta (Ukr. NIGRI), vyp. 2 M., 1959. 225 s [Papers of the Ukrainian Institute of Geological Prospecting (UkrNIGRI)]: Vyp. 2, Moscow, 1959, 225 pp. Contents: Maksimov, A.V., On the stratigraphy of the Stryy deposits in the Eastern Carpathians. Dolenko, G. N., Problems in the geologic history of the Western Carpathians. Kul'chitskiy, Ya. O., On the Krasnoputnyy "crag" of Jurassic limestones in the Bukovina Carpathians. Novosiletskiy, R.M., The problem of the structure of the Borislav underthrust. Baranov, I.G. and Yu.A. Arsiriy, Some special features of the salt tectonics of the Dnepr-Donets Basin. Baranov, I.G., A.A. Martynov and N.A. Samborskiy, On the correlation of the Devonian deposits in the eastern part of the Dnepr-Donets Basin. Martynov, A.A., The Early Paleozoic deposits of the Dnepr-Donets Basin. Martynov, A.A. and A.P. Sen', A stratigraphic scheme of the Upper Permian and Triassic mottled deposits in the southeastern part of the Dnepr-Donets Basin. Zav'yalov, V.M., The prospects for oil and gas in the northern part of the Sea of Azov. Chernyak, N.I., The history of the Black Sea basin. Romanyuk, A.F., The hydrogeologic conditions of the gas deposits in Ciscarpathia. Zhilovskiy, N.I., On the nature of the saline springs in the southeastern part of the Eastern Carpathians. Temnyuk, F.P., The stratigraphy of the Cretaceous and Tertiary deposits in the northwestern part of the Eastern Carpathians. Yurchakevich, Ya.M., Some geochemical properties of the rocks exposed by test wells in the Dnepr-Donets Basin. Timasheva, E.Ye., The use of spectrum analyses in the correlation of the sedimentary deposits of Ciscarpathia. Zemlyanskiy, N.I. and G.M. Dontsova, The properties of the aromatic hydrocarbons in certain oils of Dolina and Bitkov. Khizhnyakov, A.V. and V.M. Yurchakevich, The results of a study of bitumen occurrences in the Middle Paleozoic deposits of the southwestern end of the Russian platform. Yatsenko, Ye. F. and L.B. Lebedeva, An experiment in using the gas-exchange method to determine the organic hydrocarbons in sedimentary rocks. Sklyar, V.T., An experiment in the use of high-capacity extractors to remove the hydrocarbons from sedimentary rocks. Lukin, A.Ya., The facies of the Miocene deposit in the outer zone of the Ciscarpathian basin. Romanyuk, A.F., The ground waters of the Bitkov oil deposit.

19. Trudy Tsentral'nogo nauchno-issledovatel'skogo gornorazvedochnogo instituta "TSNIGRI", vyp. 32. M., 1959. 131 s. [Publications of the Central Scientific Research Institute of Mining Exploration "TSNIGRI"]: Vyp. 32, Moscow, 1959, 131 pp. Partial contents: Kazakevich, Yu.P., et al., The laws governing the localization of the gold-ore mineralization of the Lena district in relation to its geologic structure. Kazarinov, A.I., The geology and gold mineralization of the Kuranakh area in the Central Aldan. Fogel'man, N.A., S.G. Mirchink, A.K. Kondratenko and A.A. Saprykin, The geologic structure and the gold content of the southern part of the Shilka-Nercha interfluve (Eastern Transbaykal). Bernshteyn, P.S., N.K. Kurbanov and T.Yu. Piotrovskaya, The mercury deposits of the Vyshkov area of Transcarpathia, their ore prospects and the geologic prerequisites for locating concealed deposits. Volarovich, G.P., Ye.A. Ponomareva and Yu.M. Mikhaylov, Geologic and geophysical operations in the Tumna gold-ore deposit. Shmidt, A.I., The geologic structure and some problems of the genesis of the Southern Kurosan deposit. Andrianov, V.V., An account of the work of the Lena Combined Expedition of 1957. Vasilchenko, S.F., L.I. Stekunova and S.V. Yablokova, The main features of the geologic position of the Kuranakh ore field and the development of geophysical exploration methods for discovering and tracing ore bodies. Fel'dman, A.A. and I.V. Krut', Geophysical and geochemical investigations in the area of the Aktash mercury deposit (the Gornyy Altay). Pozhidayev, A.A., The results of geophysical operations in the Middle Urals in studying the geologic structure and locating gold-pyrite ore bodies in the zone of the Greenstone rocks. Kudryavtseva, I.A., R.Ya. Frolova and A.A. Storozhenko, Geophysical operations in the area of the October alkaline massif in 1957. Kuznetsova, L.N., A study of the flotational properties of the oxidiz[ed] minerals of rare elements. Rossovskiy, S.N. et al., A atudy of the zirconium-niobium ores of the Kalinin-Shevchenkov deposit. Dubinskiy, S.A., and G.F. Shvetsov, The replacement of the X-ray

by the radiation from radioactive isotopes in X-ray-luminescence instruments. Dubinskiy, S.A. and N.P. Kuz'mina, An investigation of the spectra for studying activized minerals for the purpose of radioactivity logging. Nedler, V.V., A testing and selection of methods of spectrum identification of rare and dispersed elements in ores, to replace chemical analysis to the greatest possible degree in calculating the amounts of reserves. Fer'yanchich, F.A., The elaboration of methods of quantitative microchemical determination of the main and accessory elements of precious minerals in heavy concentrates (zirconium, gold, tantalum niobates).

0. Uchenyye zapiski Azerbadzhanskogo universiteta, ser. geol.-geogr., no. 3. Baku, 1959. 138 s. [Scientific Notes of the University of Azerbaydzhan, Geological-Geographic Series]: No. 3, Baku, 1959, 183 pp. Partial contents: Mekhtiyev, Sh.F., Some laws characterizing the distribution of iodine and bromine in the ground waters of the various stratigraphic elements of the Caucasus. Sultanov, K.M., The stratigraphic subdivision and the extent of distribution of the Apsheron deposits in Northeastern Azerbaydzhan. Shikhalibeyli, E.Sh., G.P. Kornev and A.A. Bayramov, A Tertiary intrusive formation in the southeastern part of the Lesser Caucasus. Khalilov, D.M., The Upper Cretaceous and Paleogene deposits at the village of Zeid in the Konakhkend area of Azerbaydzhan. Mamedyarov, M.G., The alluvial deposits and petrography of the Terter River basin. Selimkhanov, N.M., The genetic types and morphology of the ores in the Akhindzha-Chay interfluve (Azerbaydzhan SSR). Shakhsuvarov, T.S., On the role of the deltaic factor in the formation of the oil-producing strata of Azerbaydzhan. Keremov, N.K., The karst caves in the Terter-Chay River basin of the Azerbaydzhan SSR. Sadigov, A.M. The geologic history of the Surakhan and Bibieybat structures in the lower member of the oil-producing stratum. Aliyev, A.G. and Akayeva, V.P., The facies and the conditions of formation of the Apsheron deposits in Northern Azerbaydzhan. Guseynov, F.G., The petrography of the Middle Jurassic volcanogenic and volcanogenic-sedimentary rocks of the Dashkesan district.

21. Uchenyye zapiski Latviyskogo universiteta, t. 21. Riga, 1959. 158 s. [Scientific Notes of the University of Latvia]: T. 21, Riga, 1959, 158 pp. Partial contents: Glazovskaya, M.A., Topographic-geochemical maps as base maps for the geochemical location of economic minerals. Yaunputnin', A.I., An attempt at a geomorphological regionalization of the Latvian SSR and its significance in topographic regionalization. Lazdan, A.Ya., The use of geomorphological mapping data for distinguishing physical-geographic topographies. Biske, G.S., K.O. Karts and O.N. Kazakova, An attempt at an analysis of the interrelationships between the tectonics, the relief and the types of natural landmarks in Karelia. Chazov, B.A. and A.M. Kropayev, Some geochemical features of the natural topographies of the Perm region.

CHRONICLE

FOURTH SESSION OF THE INTERNATIONAL ASSOCIATION FOR GEOLOGIC STUDY OF DEEP ZONES OF THE EARTH'S CRUST[1]

by

Ye. V. Pavlovskiy and N. A. Shtreys

The Fourth Session of the International Association for Geologic Study of Deep Zones of the Earth's Crust was held in September 1959, in the German Federal Republic.

It was attended by geologists from 12 countries: Belgium (including the Belgian Congo), German Democratic Republic, German Federal Republic, the Netherlands, Denmark, Spain, Norway, the Soviet Union, Czechoslovakia, Switzerland, Finland, and France.

The total number of registered participants was 50. Local German geologists participated in individual field trips and meetings, bringing the total attendance on some days up to 80 or 100.

The Soviet delegation was represented by Academicians D. S. Korzhinskiy (leader), A. A. Polkanov, V. S. Sobolev, and A. L. Yanshin, Corresponding Member L. V. Pustovalov, Doctors of Geologic and Mineralogic Sciences Ye. V. Pavlovskiy, L. N. Formozova, and N. A. Schtreis; Candidate of Geologic and Mineralogic Sciences, Yu. V. Nikitin, and Z. N. Korzhinskaya.

Unanimously elected were P. Eskola (Finland) as Honorary President of the Fourth Session; Professor J. Jung (France), President of the Vosges Session with Prof. J. Eller (France) as Vice President; Prof. E. Wegmann (Switzerland) President of the Schwartzwald Session, with Prof. W. Nieuwenkamp (Netherlands) as Vice President; and Academician D. S. Korzhinskiy) President of the Odenwald Session, with V. S. Sobolev as Vice President.

Soviet scientists participated in two previous sessions of the Association, in France and Scotland (see Izvestiya AN S. S. S. R., Ser. Geol., nos. 1, 6, 7, 1958 and no. 2, 1959).

The organizer of the session and its actual leader, as before, was General Secretary of the Association, Prof. P. Michot (Liège, Belgium). Considerable organizational help was provided by W. Wimmenauer, a Lecturer at Freiburg University.

The problem before this session was a study of the composition and geologic structure of the lower structural stage of the Hercinian folded zone of Western Europe, i. e., the basement rocks of most of Schwartzwald and Odenwald. One of the field trips was to Kaiserstuhl, located in the Upper Rhine graben and formed by Tertiary alkalic extrusives.

Leaders on field trips were German scientists: W. Wimmenauer for the Kaiserstuhl area; Professors K. Menhert and W. Tröger for Schwartzwald; and G. Trochim for Odenwald.

Kaiserstuhl is a small group of knobs in the middle part of a flat plain, typical of graben relief. This area has been studied by French and German geologists and petrographers for over 170 years. A considerable portion of the Kaiserstuhl area is covered by assorted Quaternary deposits, alluvium and loess (Riss, Würm, postglacial alluvium), with a Miocene (according to J. Söllner) massif of essexite-theralite rocks protruding from under them in places of greatest relief. This massif represents a volcanic center of tephryite lava and agglomerate. This rock complex is cut by stocks and veins of a phonolite composition, originating as a result of the second volcanic phase. Of interest are new data of W. Wimmenauer indicating the participation of carbonate rocks in the composition of Tertiary extrusives.

Tertiary intrusions and flows of alkalic lavas are associated with a small zone of uplifts in the basement of the Upper Rhine graben. In plan, this zone is oval, trending from southwest to northeast. Participating in the Kaiserstuhl

[1] 4-ya sessiya mezhdunardnoy assotsiatsii po geologicheskomu izucheniyu glubinnykh zon zemnoy kory.

structure, along with Cenozoic volcanic formations, are Lower Oligocene and Dogger sediments. The structure of the uplifted block remains obscure (horst?, anticline?); equally obscure is the role of faults which twice served as vents for magma, in Miocene time.

The one-day field trip to Kaiserstuhl afforded a chance to get acquainted with that extremely interesting segment of the southern part of the Upper Rhine graben.

Schwartzwald. As described by H. Cloos, the Upper Rhine grabben is a meridional cut in the immense domal uplift whose west limb is formed by the Vosges and the east limb by Schwartzwald and Odenwald.

The Schwartzwald mountain massif is defined by the Rhine graben in the west; by the upper Rhine valley in the south; by the upper Neckar valley in the east; and by a slightly hilly plain in the north, with the considerably lower Odenwald massif lying still farther north. Mt. Feldberg, elevation 1493 m above sea level, is the highest peak in Schwartzwald.

The central part of Schwartzwald, adjoining the Rhine graben, is formed by metamorphic schist, para- and ortho-gneiss, and anatektites, but by veins and small stocks of granite and granite porphyry. This schist and gneiss forms the lower structural stage of Schwartzwald and are late Cambrian in age, according to German geologists. The stratigraphy and tectonic structure of the metamorphic schist and paragneiss are not known, except that these rocks are gathered into complex faults generally trending north-northeast.

Detailed mineralogic and petrographic studies have revealed that schists and paragneisses of south Schwartzwald were formed by metamorphism chiefly of graywacke, arkosic sandstone, and to a smaller extent of marl and extrusive and pyroclastic formations. Those primary sedimentary and volcanic deposits carry small bodies of basic and ultrabasic rocks (diabase, gabbro, pyroxenite, and peridotite), also of a Precambrian age.

Present in the lower structural stage, besides the above-mentioned rocks, are assorted amphogneiss, metablastite, metatektite, diatektite, and palingenites of a granitic, granodioritic, and syenite-dioritic composition, typical of deeper zones of the crust.

The second zone of south Schwartzwald is the so-called culm zone which is a narrow belt of Devonian and Lower Carboniferous deposits. In plan, it is a gentle arc concave to the north, embracing the central Schwartzwald from the east and south. Concealed below the Rhine graben, the culm zone reappears in the Vosges, France.

Findings of fossil flora and a very rare fossil fauna fixes the age of these deposits as Devonian and Lower Carboniferous, through the Visean. Older Devonian deposits, as well as Gotlandian and other lower Paleozoic beds, have not been paleontologically identified and appear to be missing in Schwartzwald.

The Upper Devonian is represented by alternating fine-grained graywacke and shale with rare intercalations of marl. The Lower Carboniferous, commonly opening with conglomerate, is also made up of graywacke and shale with rare marls and oölitic limestones. Culm sediments locally are accompanied by flows of porphyrite, quartz porphyry, tuff, and volcanic breccia.

The culm zone forms the second structural stage in south Schwartzwald. This typical superimposed structure presents a system of narrow grabens within which strongly dislocated Devonian and Carboniferous deposits are cut by transverse and longitudinal normal faults producing a scaly structure of the zone.

The Upper Devonian-Carboniferous zone is accompanied by early Variscan beds, linearly deformed conformable to the zone trend, "peripheral" granites which metamorphose the Upper Devonian. These granite bodies, both hybrid (Machbacher) and non-hybrid, are emplaced between Precambrian and Devonian; locally they participate in the structure of individual scales in the graben system. Extremely interesting is the fact that in isolated places Devonian deposits have been metamorphosed to gneiss.

The third zone of South Schwartzwald is the so-called granite province located east and southeast of the culm zone. Developed here are mostly Variscan granites of several generations and different compositions. In addition to deformed Upper Devonian granites, there are undisturbed granites of the same age and undisturbed Lower and Upper Carboniferous granites accompanied by corresponding vein series.

Variscan granites rest among metamorphic schist, amphibolite, and gneiss, presumably Precambrian. According to K. Choenes and W. Wimmenauer, diatektites and syenite-dioritic syntektites in their midst originated by the interaction of granite intrusions with these ancient emplacing rocks.

The fourth zone, and the third structural stage of south Schwartzwald, is formed by Permian and Triassic deposits extending along the eastern slope of the massif and sharply transgressive and unconformable upon the Precambrian and the granite intrusions. Assigned to the Permian, along with sedimentary rocks, are thick flows of quartz porphyry locally developed in central Schwartzwald. These porphyries are manifestations of the most recent Variscan igneous activity.

Students of Schwartzwald believe that this graben-like zone of Paleozoic rocks (the culm zone) was formed in the Early or Middle Devonian, as a result of block movements in the basement. Subsequently, the faults in this zone were reactivated repeatedly, with new faults opened during both the Late Devonian and the Permian and Carboniferous.

The first folding involved Paleozoic rocks, as early as the close of Late Devonian, according to J. Scheffer. The intrusion of Variscan granite is also assigned to it. Then came the Bretonian and Sudetian or Asturian phases, with tectonic movements of one of the last two bringing about the scaly structure.

Unfortunately, because of the inadequate knowledge of the stratigraphy and folding of these metamorphic formations, regularities in the distribution of numerous intrusions and in the tectonic structure of Schwartzwald remain obscure.

Odenwald, the study of which was made on the last two days of the field trip, consists of two tectonic parts. Its eastern segment, the so-called Bollstein Odenwald, is separated from the western (Bergstress Odenwald) by the major and old Otzberg fault. The western part of Odenwald is cut off by the Upper Rhine graben-border fault.

Rocks forming the lower structural stage of the Hercinian folded zone are exposed in both segments of Odenwald. The oldest is paraschist preserved in discontinuous bands among granitoids and other igneous rocks. The crystalline schists are diversified in composition, and include biotite, biotite-granite, dimicaceous, feldspathic-micaceous, amphibolic, quartz-biotite, and graphite schists; graphic quartzite, kinzigite; plagioclase-cordierite and corundum-cordierite schists; and assorted types of hornfels. The age of these crystalline schists is undoubtedly Devonian. It is the opinion of German students that the age of this ancient sedimentary series is most probably Algonkian.

The tectonics of these crystalline schists is very complicated. Among the identified trends, there are the "Rhine", i. e., meridonal, regarded as pre-hercinian and the oldest; also the "ore-mountain," northeastern, typical of the Saxo-Thuringian zone of hercinids and assigned to the Lower Carboniferous. The northeastern trends of of fold structures are very sharply defined, which suggests a deep-seated remodeling in the ancient basement of Hercinian folding.

Assorted igneous bodies, represented according to G. Klemm by granite, diorite, and gabbro, make up most of the Oldenwald surface. In plan, these igneous bodies are usually elongated in conformity with the "ore mountain" Hercinian trend. Recent studies have shown that the granites of G. Klemm belong to the granodiorite family. Some of the granites (the so-called "tromm granites") should be assigned to the quartz mon zonite family. All of the Odenwald "granites" are marked by a banded texture. The transition from true paragneiss to "granites" is very gradual.

The field trip was confined to a small area of West (Bergstress) Odenwald, in the vicinity of Lindenfelse and the mediaval Frankenstein castle.

In recent years, E. Nickel has carried on a detailed study near the village of Knoden, in the vicinity of Lindenfelse. He recognizes the following igneous-tectonic stages (phases) of development of the Hercinian basement: 1) ancient pre-Hercinian kinetic metamorphism; 2) plagioclase metablasticism and dioritization without addition of new material; 3) granitization, brought about by an addition of new material; and 4) younger kinetic metamorphism. Ancient, probably Algonkian, sedimentary rocks underwent a pre-Hercinian kinetic metamorphism and changed to mica schist and dark biotite-plagioclase gneiss. Relicts of the first metamorphic-stage rocks are poor in quartz and lacking in K-feldspar.

The second metamorphic stage (plagioclase metablasticism) was marked by an isochemical process of recrystallization which led to the appearance of banded amphibolite and biotite-hornblende-plagioclase "hornfels". That process went even farther, to the appearance of "diorite hornfels" with a regular orientation of biotite plates. The final stage of dioritization is massive diorite with hornblende predominant over biotite. Recently, massive diorite has been regarded by E. Nickel as the end product of ultra-metamorphism.

The third stage of geologic history of the ancient Odenwald basement is marked by the process of granitization, brought about by an influx of alkalies and by the appearance of metablasts of K-feldspar and oligoclase (No. 25-30).

The fourth and last stage, a younger kinetic metamorphism is expressed in the development of a plane-parallel texture and in the appearance of dioritic gneiss and granitoid gneiss.

A detailed (1:2000) petrographic map of the vicinity of Knoden, compiled by E. Nickel, is a good representation of the aforementioned brief exposition of the history of metamorphism of this Odenwald area. These concepts are probably true, to some extent, for a larger part of west Odenwald.

A large plutonic body of gabbro was seen on the last day of the field trip, in the vicinity of the Frankenstein castle; it had been studied in detail by H. Trochim. This gabbro massif is

strongly differentiated and carries peridotite lenses.

The massif is also cut by odinite veins. Very diversified in composition are allogenic inclusions in the gabbro; among them are "beerbachite" and "gabbroporphyrite," erroneously assigned to vein formations, by G. Klemm. As a matter of fact, they are xenoliths of plagioclase-pyroxene hornfels with a granoblastic texture. Such rocks have been observed in the outer contact zone of the gabbroid massif. Also present are xeonolths of corundum-magnetite, corundum-sillimanite, and sillimanite hornfels, amphibolite biotite-plagioclase schists, and calcareoussilicate rocks. A map by H. Trochim with isolines of anorthite content in the grabbomassif is of interest. These lines do not follow the massif outlines, which trend northeast, but veer appreciably toward the meridian, to describe a "Rhine"-trending oval. The massif appears to extend far to the north, plunging under the crystalline schist. The "core" of the massif is located in the western part of the field of gabbro development.

The Trochim map correlates well with a map of magnetic anomalies by G. Reich (1951). It follows from G. Reich's data, now corroborated by petrographic study, that intrusive processes are closely related to the tectonics of the Rhine graben. Many students (H. Kloos, S. Bubnoff, G. Ruger) regarded the graben as an ancient weakened crustal zone.

The Frankenstein gabbro massif is emplaced in ancient (Hercinian) igneous formations of Odenwald. It is possible that the gabbro magma ascended along the fault which now limits the Upper Rhine graben in the east.

Observations made during the Kaiserstuhle, Schwartzwald, and Odenwald field trip can be summarized as follows:

1. The field trip was very interesting and fruitful. Soviet geologists had an opportunity to get acquainted with manifestations of Tertiary volcanism within the Upper Rhine graben and with rocks at the base of the hercinids, which have undergone great transformations in the course of Hercinian orogeny.

2. Despite the high quality of research done by German geologists, only petrographic methods have been used mostly, up to now; lithologic and stratigraphic differentiation of paleongologically barren formations, assigned to the Upper Cambrian and locally to the Devonian, is rather neglected.

3. There is a lag in detailed geologic mapping of Schwartzwald and Odenwald. A modern geologic petrographic map was compiled and published in 1958 at a scale of 1:50,000, by R. Metz and G. Rein, for South Schwartzwald only. Odenwald is represented by a 30-year old map at a scale of 1:100,000 by H. Klemm.

4. The present maps are petrographic maps rather than geologic maps. They do not adequately represent the tectonics of the areas of development of ancient metamorphic, sedimentary, pyroclastic, and volcanic rocks.

5. The demonstration of natural objects was excellently organized. The introduction of a field polarization microscope, thanks to which each participant had a chance to observe rocks not only in outcrop and hand specimen but in thin section as well, was very useful.

An obvious growth in interest in the activity of the International Association for the study of Deep Zones of the Earth's Crust should be noted. There was a marked increase in the attendance at the Fourth Session compared with the preceding ones, both from the Soviet Union and from abroad. The time and place of the Fifth Session was discussed. It is scheduled for 1961, in the Czech Massif (there will be no session in 1960, because of the International Geological Congress at Copenhagen). Czech and East German geologists will organize field trips.

During its entire visit to West German, the Soviet delegation was shown every consideration and high esteem. Significantly, three sessions of the Association were presided over by Soviet scientists. Friendly relations, initiated in earlier sessions, prevailed among all participants. There were many requests from foreign scientists for works of Soviet scientists.

Most foreign scientists showed great interest toward modern Soviet geologic literature. In West Germany, as well as in England and France, as previously noted, some scientists study the Russian language and read Russian literature in the original. Foreign scientists expressed hope for a further consolidation of relations with Soviet scientists.